RESEARCH COUNCIL OF ZIMBABWE

Leadership, Innovation and Development

Zimbabwe International Research Symposium 9th Edition Book of Proceedings

13 - 14 FEBRUARY 2013

Theme: "Driving Socioeconomic Development through Research Output"

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EDITORIAL

The Zimbabwe International Research Symposia (ZIRS) are held biennially by the Research Council of Zimbabwe, (RCZ). The overall purpose is to bring together researchers, policy makers and industrialists from within and outside Zimbabwe. Since 2007 the RCZ has successfully held eight symposia' with the following Themes;

- **2007: Knowledge Based Development for Zimbabwe**
- **2004: Impact of Innovative Science and Technology on National Wealth Creation**
- **1999: A century of Science and Technology Challenges for the Next Millennium**
- **1996: Towards Capacity Building in Science and Technology**
- **1994: Advances in Productive and Sustainable Applied Technologies**
- **1992: Innovation, Self Reliance and Development**
- **1990: No theme**
- **1988: No theme**
- **2013 Driving Socioeconomic Development through Research Output.**

The objectives of the present symposium (ZIRS 2013) are;

- To provide a platform to stimulate and sustain informed decision making in all facets through research.
- To enable researchers, policy makers and users of research results in Zimbabwe and the rest of the world to exchange information, research findings and ideas.
- To promote smart partnerships among researchers, industry, commerce and various stakeholder communities so as to ensure application of research findings.
- To create new knowledge for sustainable development.
- To pay tribute to hard work, dedication and achievement by the country's finest researchers.
- To cultivate use of research results in industry including the service industry, commerce and government.
- To motivate young researchers to strive for excellence in research.
- To encourage application of research findings.
- To promote informed decision making.

- To celebrate research excellence.

In all, the symposium received 54 papers, 52 of which were accepted by the reviewers and 47 papers were presented at the symposium that is 90% of the accepted papers were physically presented. This in itself was a very respectable achievement. It is from all the accepted papers that the current PROCEEDINGS are generated.

The proceedings are presented as five distinct sections under the headings **Agricultural Sciences; Environment and Natural Resources; National Security; Health Sciences; and Social Sciences**. The sections were drawn from the National Research Priority Area, which were the focus of the symposium, which are

1. **Social Sciences and Humanities**
2. **Sustainable Environment and Natural Resources Management**
3. **Promoting and Maintaining Good Health**
4. **National Security**

The opening addresses are preceded by the Keynote speech which was appropriately titled "REALISING THE POTENTIAL OF SCIENCE AND TECNOLOGY TO IMPROVE AFRICAN LIVELIHOODS". The keynote speech gave a sobering reminder of the contradictions inherent in the economic growth, science and technology in Africa. While there is a general annual growth of 5% across Africa, up to 40% of the populations live below the poverty datum line.

In a sense, the keynote speech set the scene for the presentation of the plenary papers. The speech hinted on the agricultural sciences potential of Africa by informing the delegates that 60% of the world's uncultivated land and 25% of land for agriculture is in Africa. However we have to take cognisance of the fact that perhaps one of the major and route cause of Africa's problems is that there is limited exploitation of science and technologies. The symposium is one way of demonstrating that there is an attempt to addressing this problem.

In particular, most of the agricultural papers presented at the parallel sessions have a palpable applied science and technological slant. The paper on the comparison of the effectiveness of organic manure, inorganic fertilizers and integrated soil fertility management on coffee plant growth is one example, so is the use of plant extracts to control plant pathogens in "Efficacy of Botanical Extracts from Garlic on controlling Potato Soft Rot Pathogens". The use of satellite remote sensing to estimate maize yield is a paper which seemed to directly answer the call from the Keynote Speech.

The recent diamond boom in Zimbabwe is topical globally. It is therefore gratifying that the "Environment and Natural Resources" section had a paper presented on "Automation systems for the Optimisation of Diamond processing Technologies in Zimbabwe". The paper reported on the results of an evaluation of the level of scientific and technological preparedness of

Zimbabwe compared to other global diamond processing industries. Ultimately the objective is to add commercial value to the diamond industry in Zimbabwe. This is a positive direction to take for Africa in general as far as exploitation of its natural resources is concerned.

In the "Promoting and Maintaining Good Health" section it is pointed out that use and implementation of Electronic Health Records significantly revitalises health delivery, as it is cost effective, efficient and it increases patient safety.

One of the Social sciences papers reveals that the socio-cultural impact of electronic media on youth points out that youth spent a lot of time on electronic media and they seem to benefit by getting educational value, research skills and social networking skills.

The few papers quoted here give a glimpse of the diversity and scope of the research work being conducted especially in Zimbabwe. One hopes and is encouraged to believe that this trend will continue into the next symposium and the next one after that and so on!

Chief Editor

Professor CFB Nhachi

ZIMBABWE INTERNATIONAL RESEARCH SYMPOSIUM PROGRAMME : 13-14 FEBRUARY 2013

Theme : Driving Socioeconomic Development through Research Output

13 February 2013				
Time	**Activities**			
0730-0900	Arrival, registration and teas			
15 mins	**PLENARY SESSION :** **Chairman : Dr C Maponga**			
0900-0915	Objectives of the ZIRS and symposium logistics in plenary **(Dr D Garwe)**			
	PARALLEL SESSIONS			
	1: SOCIAL SCIENCES AND HUMANITIES **Morning Chairman:** Dr F Mangena **Venue:** Committee Room 6	**2: ENVIRONMENT** **Morning Chairman:** Dr A Murwira **Venue:** Committee Room 5B	**3: AGRICULTURE** **Morning Chairman :** Prof M Shoko **Venue:** Committee Room 5A	**4: PROMOTING AND MAINTAINING GOOD HEALTH** **Morning Chairman:** Prof C F B Nhachi **Venue**: First Mezzanine
1000-1020	Socio-cultural impacts of electronic media and the prevalence of media education skills: A nexus of concoctions for positive youth culture development **(Ms L Jambaya)**	Soil erosion and its effects on arable land and river systems of Zimbabwe. Is this a catchment management issue: A look beyond the fast track of land reform program **(Mr K Nyoni)**	Soil quality and cropping patterns in Mutema irrigation scheme, Zimbabwe **(Mr A Chemura)**	Dental fluorosis : Prevalence and severity of dental fluorosis amongst 5-6 and 12-16 year olds in Tsholotsho district : Zimbabwe **(Mr C Dunga)**

Time	Activities			
1020-1040	The Socio-economic impact of vocational education skills training centres among the Bulawayo youths during the period 2008 to 2012: A case study of Lobengula and Sizinda training centres **(Mr N Sibanda)**	Climate change, institutional arrangement, sustainable agriculture and climate change adaptation in Chivi district, Zimbabwe **(Mr H Chikowa)**	Evaluation of promising spring bread wheat (Triticum Aestivum L) breeding lines under irrigated multi-environment conditions in Zimbabwe**(Mr B Mutari)**	Impact of a preventive maintenance program for HVAC systems in hospitals: A case study of Kitwe central hospital **(Dr B Mwanza)**
1040-1100	National and regional approaches to multilingualism in Africa **(Dr A Kasonde)**	A remote sensing-rainfall model to understand distribution of surface water in Southern African semi-arid rangelands **(Mr Zvidzai)**	Assessing effectiveness of botanical extracts from garlic and neem on controlling potato soft rot pathogens **(Mr V M Paradza)**	Urinary schistosomiasis: Lack of knowledge could be hampering eradication efforts **(Mr N H Paul)**

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1100-1120	Liquidity derivatives as a solution to Zimbabwe liquidity problems **(Mr W Chagwiza)**	Indigenous knowledge farming systems that have contributed to sustainable land management in Zhombe communal lands **(Mr N J Ndiweni)**	Assessment of the adoption and use of indigenous knowledge systems in the control of grain weevils in stored small grain in Matopo district in Matebeleland South province of Zimbabwe **(Mr P Sibanda)**	Advanced claypot defluoridatin technology **(Mr C Dunga)**
	Change of Chairmanship in Parallel Session 4 : Promoting Good Health : New Chairman : Dr W B Mujaji			
1120-1140	The relationship between ownership structure and firm performance : Case of Zimbabwe 2009-2011 **(Mr W Gwarimbo)**	Monitoring and evaluating the impacts of subtle deforestation on tree diversity and tree density in Savanna **(Mr R B Mapfumpo)**	Agronomic strategies for optimizing wheat yields in the south eastern lowveld of Zimbabwe **(Mr C D T Mhadzo)**	The removal of PCR inhibitors from human bile using ion-exchange chromatography **(Ms W E Chipato)**

Time	Activities			
1140-1200	An analysis of the effectiveness of defensive driver training and driver retesting in the reduction of road training accidents among public service vehicles drivers : The case of Bulawayo Metropolitan province (Mr O Masunda)	Fuzzy logic control for the maintenance of chains in the bottle washer in the Krones machinery of Germany (Mr T Mushiri)	Performance evaluation of a small-scale solar tunnel dryer for drying tomatoes (Mr J Madzore)	The extent to which Mutare Teachers' College is a health promoting college (Mrs J Razuwika)
	Change of Chairmanship in Parallel Session 1 : Social Sciences and Humanities : New Chairman : Dr N Mhiripiri			

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1200-1220	Social capital and the informal vendor economy in the dollarised Zimbabwe : A case of Mucheke suburbs in Masvingo urban **(Mr S Marapira)**	Properties of Afzelia qaunensis (mukamba tree) suitability for establishment as a commercial timber in Zimbabwe **(Mr T Runesu)**	A method to estimate maize yield in Zimbabwe using satellite remote sensing **(Mr F Kuri))**	Free but expensive :An assessment of healthcare facilities in remote rural and farming communities **(Mr J Mugumbate)**
1220-1240	Psychosocial healing and reconciliation in post conflict Zimbabwe. The missing link in Zimbabwean politics **(Mr M C C Musingafi)**	Solar energy use in Zimbabwe **(Mr E Mhukayesango)**	Improvement of seed size in cowpea (Vagina unguiculata (L.) Walp,) through mutation breeding **(Mr P M Matova)**	Electronic health records and their role in the revitalisation of Zimbabwe's health delivery system **(Dr P Ngulube)**

Time	Activities			
				PARALLEL SESSION 5: NATIONAL SECURITY : Chairperson : Dr W B Mujaji
1240-1300	An investigation into the causes of fraud in banks in Zimbabwe **(Mr J Tembo)**	Modelling fire risk areas in Zimbabwe for 2012 fire season **(Mr N Nondo)**	Crop forecasting as an adaptive strategy to climate change and variability in semi-arid regions of Zimbabwe **(Mr F M Simba)**	The impact of the internet on the profitability of retail business models. An empirical analysis of the profitability of e-tailing vis-a-viz traditional retailing **(Mr T Chinyamakobvu)**
1300-1400	**LUNCH BREAK**			
Change of Chairmanship in Parallel Session 2: Environment : New Chairperson : Mrs C Tagwireyi				
Change of Chairmanship in Parallel Session 3: Agriculture : New Chairman : Prof D Z Moyo				
1400-1420	Where did our money go? Answering the questions behind loss of value to pensioners in Zimbabwe after multicurrency adoption **(Mr T Chowa)**	Remote sensing and GIS applications on change detection study in Mafungabusi forest – Gokwe (Zimbabwe), using multi temporal satellite data (From 1992) **(Mr A Chinofunga)**	Local perceptions of livestock grazing and rangelands in communities adjacent to the northern Gonarezhou National Park, Zimbabwe **(Mr E Gandiwa)**	

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1420-1440	An investigation into the causes and effects of spouse abuse: A case study in Nyanga urban in Manicaland province, Zimbabwe **(Mr O Kanjanda)**	Appropriate automation systems for the optimization of diamond processing technologies that can resultant production costs ratio per carat **(Mr C Kanyunga)**	Decision support systems in commercial agriculture: case study on ICT adoption and use by farmers in the western cape wine industry to assist emerging farmers in decision making **(Mr G Simbanegavi)**	
1440-1500		Energy management matrix assessment as a tool for improving organizational energy performance **(Mr B Zeyi)**	Determinants of successful commercialization of indigenous innovations in Zimbabwe: The case of E10 **(Mr F Saruchena)**	
Time	**Activities**			
1500-1520		A robust communication protocol for a stadium system turnstile counting system**(Dr E T Kapuya)**	Development of mechanised poultry de-feathering process for small scale farmers in Zimbabwe **(Mr L E N Nyemba)**	

Time	Activities			
1520-1540		Towards an operational geographical information system for monitoring vector species' habitat change in a changing climate **(Mr F Matawa)**	Adjustment of cropping patterns to mitigate the effects of climate change in Zimbabwe **(Ms R Masvodza)**	
1540-1600		Testing gum Arabic as potential binder in charcoal briquetting **(Mr G Sibanda)**	The growth response of coffee plants to organic manure, inorganic fertilisers and integrated soil fertility management under different irrigation levels **(Mr A Chemura)**	
1600-1620		Using molecules and models to manage biological invasion for a sustainable future **(Dr D Thompson)**	Investigating the potential use of water hyacinth for biogas and organic fertilizer production **(Mr E P Sibanda)**	
PLENARY SESSION 2 : CHARPERPESON FOR THE INTERNATIONAL CENTRE SCEINCE (ICSU): Mrs S Mutize				
1625-1700	Future Global Earth Africa Initiatives			

OFFICIAL OPENING SPEECHES

WELCOME ADDRESS BY THE CHAIRMAN OF THE RESEARCH COUNCIL OF ZIMBABWE MR EBEN MAKONESE AT THE OFFICIAL OPENING CEREMONY OF THE 7TH SYMPOSIUM ON "DRIVING SOCIO-ECONOMIC DEVELOPMENT THROUGH RESEARCH OUTPUT". 13–14 FEBRUARY 2013, HARARE INTERNATIONAL CONFERENCE CENTRE.

Protocol Observation

Welcome

I am delighted to be with you this morning at our official opening of the 9th Zimbabwe International Research Symposium and Award Presentation Ceremony. You have all worked hard at preparing your papers for the symposium. Some of you travelled long distances. Others, like students from Chibero Agricultural College, came to learn and network. I thank you all for coming.

Your host, the RCZ was established in 1986 by an Act of Parliament. Its mandate is to Promote, Direct, Supervise and Coordinate Research Institutions. The vision of the RCZ is to be the pivotal leader, guiding all research towards the sustainable development of Zimbabwe.

Establishment of RCZ was a significant step in scientific, Economic and social development of Zimbabwe. It underpins economic growth and prosperity.

At the beginning of the three-year period ended 31 December 2012 the RCZ developed a strategy whose goal is improvement of all aspects of life in Zimbabwe. The Strategy covers four strategic areas: namely

- National Research Prioritisation
- Research Control and Coordination
- Research Promotion and Publicity
- Research Mobilisation, and
- Registration of Foreign Researchers

This occasion today consists of the official opening of the symposium, giving the summary of previous day's symposium proceedings, the Keynote Speech and presentation of Awards. Presentation of the awards recognises researchers who, in the opinion of their peers, have excelled in their work.

The summary of the proceedings of the symposium will be most useful as this will inform us about the major issues which came from the plenary sessions we could not attend.

Now it is my pleasure to give a special welcome to Dr Edith Mdela- Mntla Professor Monte Jones and the Honourable Deputy Prime Minister, Professor Mutambara.

Dr. Edith Mdela-Mntla, the Executive Director of the International Council for Science. Her Speech, yesterday, on Future global Earth: Africa Initiatives was insightful

Professor Jones will give the Keynote Speech. He is an International known researcher who has won many awards. You will hear more about him at his introduction.

Hon. DPM, Prof. Mutambara will officially open the symposium. The DPM is an exciting speaker whose passion for academic excellence and research are well known.

I welcome you all and trust you will find the morning both rewarding and inspiring.

SPEECH TO INTRODUCE THE GUEST OF HONOUR BY THE ACTING MINISTER OF SCIENCE AND TECHNOLOGY DEVELOPMENT, HONOURABLE N. CHAMISA AT THE OFFICIAL OPENING OF THE ZIMBABWE INTERNATIONAL RESEARCH SYMPOSIUM: 13-14 FEBRUARY 2013, HARARE INTERNATIONAL CONFERENCE CENTRE.

The Honourable, Deputy Prime Minister, Professor A. G. O Mutambara ; Master of Ceremony and Permanent Secretary for Science and Technology Development, Professor F.P. Gudyanga; Honourable Ministers here present; Senior Government officials, Permanent Secretaries here present; Vice Chancellors of Universities; Heads of Colleges and Polytechnics; Captains of Industry; The Research Council of Zimbabwe Chairman , Mr. E. M Makonese and your Board; the Executive Director of the RCZ Mrs. S. Muzite; Symposium participants; Distinguished Guests; Ladies and Gentlemen.

We are gathered here for an important national event, namely the ninth Zimbabwe International Research Symposium (ZIRS). This event is of paramount importance to the nation as it provides a platform for promotion of research through presentations and networking at various levels. We are working, Honourable DPM, to make Science and Technology an integral part of both individual and national development. The Ministry continues to coordinate and monitor the implementation of the National Science and Technology Policies and in this case the 2nd STI Policy which was launched by His Excellence, President R.G. Mugabe, in June last year. We continue to facilitate cooperation in Science and Technology and R&D with regional and international partners. We are striving to establish a credible database of public domain research. Honourable DPM, the MSTD is committed to enhancing capacity of Small to Medium Enterprises to utilise Science and Technology. We are also identifying and promoting special science and technology talents, supervising and monitoring the activities of R&D and Science and Technology Institutions and Agencies established under the Research Act.

Honourable DPM, in the year 2012, the MSTD achieved the following: Launch of the Second Science and Technology Policy; Finealt Engineering completed the construction of the Bio-diesel mini-plant and are embarking on the setting up of a bio-diesel testing laboratory, among others; Verifying Engineering have constructed the Air Separation Unit for the Coal to Fuel project. The Ministry has been identifying recipients of the Innovation and

Commercialisation Fund for commercialisation of R&D projects and for carrying out R&D projects. The former are loans and the latter are grants. Hon. DPM, as you know, one of the most exciting development in S&T globally is the emergency of Nanotechnology which is transforming radically the way science and technology in all fields is carried out. In order to ensure that Zimbabwe is not left behind, the Ministry has set up a National Nanotechnology Programme. This is being coordinated by an expert from the University of Zimbabwe, Dr. Maponga, from the School of Pharmacy. We were able to engage him through the generous support from the Public Service Commission. He is assisted by a National Coordinating Committee of experts in the area of Nanotechnology. To roll out this programme we are organising the 2nd Symposium on Nanotechnology next month. You will recall that the first symposium on Nanotechnology was organised by the Zimbabwe Academy of Sciences in March 2010. .

The recently reviewed Mid Term Plan (MTP) recognises that development in Science and Technology is important for improving efficiency and effectiveness of doing business. The MTP recognises innovation as the primary driver for growth and development thus improving people's lives. Honourable DPM, the MTP policy objective for Science and Technology is to enhance the country's competitiveness through processing and value addition of primary products and the encouragement of innovation across all sectors.

The importance of availing funds for research cannot be over emphasised. In line with the AU recommendation the government has agreed in principle to fund research to at least 1% of GDP. This is the minimum if Zimbabwe needs to benefit from our research. We are aware of the budgetary constraints that characterise our national economy. It is for this reason that the Research Council of Zimbabwe embarked on a national research prioritisation exercise. The Government has accepted the results of this prioritisation exercise. This has led to the establishment of a funding disbursement framework to facilitate promotion of competitive research in line with those priorities.

Since 1988 the RCZ has successfully organised and hosted eight Zimbabwe International Research Symposia. The 2013 symposium theme "Driving socio-economic development through research output" is a poignant call for partnership between industry and our local institutions of research. It is therefore a pleasure to witness the work of our scientists and researchers as we congratulate the Research Council of Zimbabwe, for successfully

organising this international research symposium to promote advances in biotechnology, ICT and nanotechnology which open vast opportunities for economic growth for the country.

I would like to express our sincere gratitude to the Ministry of Finance and the rest of the Government of Zimbabwe for its tremendous effort to make this 9th edition of the ZIRS a successful event. Let me assure you once again that the Ministry will continue to support the RCZ to ensure the successful hosting of future symposia.

Director of ceremonies, our Guest of Honour today was Managing director of Africa Technology & Business Institute (ATBI) and Professor of Operations Management at UNISA SBL. Former Standard Bank Director (Payments) with responsibilities in 17 African countries. Research Scientist and Professor of Robotics and Mechatronics from the Massachusetts Institute of Technology (MIT) and NASA, with business experience and skills as a Management Consultant with McKinsey & Company. Professor of Business Strategy at Kellogg Business School, USA.

Honourable DPM is a high technology expert and leader, global strategy specialist, and an entrepreneur who advises senior managers and business leaders of global companies. Community leader, public intellectual and activist, extensively involved in socio-economic-political issues in both the U.S. and Africa. He is an author of three Engineering books and 27 refereed journal papers. A Rhodes Scholar, with an MSc (Computer Engineering) and a PhD (Robotics & Mechatronics) from Oxford University, UK; and a BSc (Hon) (Electrical Engineering) from UZ.

Honourable DPM, it is my honour to invite you to officially open this 9th edition of the Zimbabwe International Research Symposium.

I THANK YOU

THE OFFICIAL OPENING SPEECH BY THE HON DEPUTY PRIME MINISTER OF ZIMBABWE PROF ARTHUR MUTAMBARA AT THE OFFICIAL OPENING OF THE ZIMBABWE INTERNATIONAL RESEARCH SYMPOSIUM: 13-14 FEBRUARY 2013, HARARE INTERNATIONAL CONFERENCE CENTRE.

Research Output as the Key Driver of Country Competitiveness and Economic Growth.

This is an important symposium as it allows Zimbabwe to make a mark on global research. In pursuit of this agenda, research results by Zimbabwean scientists must be publicised and applied, while Government has an obligation to create an enabling and supportive environment for research. The theme: *"Driving Socio-economic Development through research output"* is very fortuitous as it places Research and Development at the centre of our national development.

As we do this, it is also important to understand the Zimbabwean context where we are; discovering new minerals, embarking on processing supported by research, driving value of addition of our minerals, and pursuing meaningful economic growth. We aspire to increase research funding to 1% of GDP and we are establishing our National Research Priorities together with a National Research Database.

There is need to embrace emerging technologies for national development including Nanotechnology, Biotechnology, ICTs, Cloud computing, Big Data, ICT Platforms and Convergence, Environment/Climate Change concepts, and that distinguished field of Robotics and Mechatronics. The myth that the most advanced technology is for the rich North has been shattered. There is opportunity to leapfrog by adopting these new technologies in emerging markets.

Research output is the key driver of country competitiveness and economic growth. However, it is important to understand what constitutes country competitiveness. It is driven by economic performance, Government efficiency, business efficiency, infrastructure, research output leverage and quality of life. The WEF Global competitiveness Index is broken down into three major drivers; Basic Requirements 60%, Efficiency Enhancers 35%, Innovation and Sophistication 5%, making a Global Competitiveness Index of 100%.

On the other hand we must define and understand economic development beyond the traditional definitions of GDP and GDP growth. These metrics are inadequate. We should look at Per capita income, Gini Coefficient (measurement of Income Inequality), nature of growth, social and political issues, the role of values and spirituality, and ICT uptake (penetration, connectivity, infrastructure, bandwidth, pricing, and competition). We must seek to master quality growth which is Strong, Shared, Sustainable, Green (low carbon), regionally and continentally, and leading to better quality of life for the citizens.

The research ecosystem must address issues of productive Research and Development, effective use of technological advances, solutions for sustainable development, technology developed products and processes, high value, high quality and competitive products and

services. All this must be rooted in inclusive socio-economic growth based on a team approach and learning organization ethos.

The reasons why research output uptake is low must be understood. These include; the assumption that spin-offs from nuclear energy or space programs will industrialise countries. Many basic human needs such as health and education are not being given the support needed; the fallacy that pure research leads to technology development then to products, open new markets or conquer existing ones; the Naïve "linear theory" or "cradle-to-grave" approach to science and development; and unanticipated problems that arise requiring re-examination and adaptation at the earlier stages.

What needs to be done to increase uptake of research must then proffered, including; provide the expertise or the adaptations necessary to make the best use of the imported technology; Incorporate new science into education (Nanotechnology); a well-trained work force; high-quality education early in development; teaching of modern science, technology or medical schools should not be restricted to the same old classical textbooks; active scientists who read and generate current literature and are capable of conveying latest advances to their students. Development requires modern agriculture, industrial systems, and education and there is need to adapt and develop technologies appropriate to our local circumstances. There is need to strengthen education, and expand our roles of researchers and scientists as advisers in both government and industry.

What will success look like at the end of this symposium? We must ask this question. This ZIRS conference will be said to be successful if there is; increased Advocacy for Research by Government; Recognition & Respect for Research; improved Research Output and impact: increased impact on Food Security, Health, Education, Industry; adoption of a Collaborative Approach; an Adaptive Ecosystem Approach; clarity on research Policy, and financing.

We must understand why Value Addition is not happening in Africa in general and in Zimbabwe in particular. The reasons include the following; Pursuit of "easier" trade options; Quick buck for corrupt regimes or officials; Lack of a Clear Industrialization Strategy; Absence of the enabling and facilitative framework; Lack of required (1) New Technology, (2) New Human capital, and (3) New cash and unfair trade; and Worshipping the false Anti-Protectionism Gospel. The Rich North disincentivises the Poor South from value addition. It is not in the interest of rich industrialised countries to encourage emerging economies to add value to their products. We are going to do it in spite of them.

The following must be done to drive beneficiation; Resolve the identified barriers; adoption of value addition driven National Vision, Strategy, and Industrial development Plan; Delayed gratification, long term planning; Timeline and planning; New Technology, New Human Capital, New Cash; and new mindset. Contrary to conventional wisdom protectionism is not necessarily without merit. In fact most of the countries that have industrialized, have engaged protectionism of sorts.

As we conclude we restate that research output is a key driver of socio-economic development. It drives both competitiveness and economic growth. But for this to happen we

need an ecosystem approach. We need adaptation of solutions to local problems. New technologies present opportunities for leapfrogging. We must seek to enhance the human experience and address the future needs of society. I want to salute the RCZ and its sister institutions for this great symposium.

Congratulations to all the Research Award Recipients, Makorokoto, Amhlope.

I declare the 2013 ZIRS officially opened

Keynote Speech

Realising the Potential of Science and Technology to Improve African livelihoods

Monty P. Jones

Executive Director, Forum for Agricultural research in Africa and Chair of the Global Forum on Agricultural Research

Introduction

The perception of Africa in the 21st Century has changed dramatically from being the 'hopeless continent' to a continent on the rise. The region has sustained economic growth of 5% per year which far exceeds its performance in previous decades. According to the Economist (2011), over the ten years to 2010, six of the world's ten fastest-growing economies were in sub-Saharan Africa. Sustained growth has led to the emergence of a genuine middle class in many African countries and investors are being drawn towards the continent because it offers the highest rates of return on investment (Dorr *et al.,* 2010).

Africa's rise is attributed to internal and external factors, notably macro-economic reforms initiated in the 1990s, improved political stability, more favourable commodity prices driven by increased demand from emerging economic powers, especially China, and increased foreign direct investment.

However, not all Africans are benefitting from the continent's recent economic prosperity. Poverty and hunger remain severest on the continent with 40% of the population living below the poverty line and one third unable to meet minimum dietary requirements. Unemployment is emerging as a major challenge and overall 74% of the 50 lowest-ranked countries in terms of human development index are in Africa (UNDP, 2011). Evidently, Africa's rise is associated with growing inequality. Presently, Africa is home to six out of the ten most unequal countries in the world.

Clearly, Africa needs to rethink its growth strategy and pursue a more equitable one which benefits the poor and vulnerable (including the youth) as well. Since most of the poor derive their livelihood from agriculture, improving the performance and profitability of the sector is

an effective way of reducing poverty and hunger. Thus, a more equitable strategy should lay emphasis on agriculture, especially in the initial stages.

In this era of globalisation and knowledge-driven development, science and technology (S&T) plays a pivotal role in raising competitiveness and ultimately economic growth. It is therefore not surprising that the widening development gaps between nations and regions are increasingly linked to corresponding gaps in S&T. Africa's low human development index is therefore linked with its limited application of S&T. For example, because Africa's S&T capacity is under developed, it is compelled to rely on the outside world to extract and add-value to its resources thereby foregoing considerable benefits in terms of revenue and employment. Furthermore, because Africa has the lowest rates of adoption of productivity enhancing agricultural technologies, its farmers register the lowest crop and animal yields.

African leaders recognise that achievement of the continent's goal of economic transformation is conditional on its capacity to effectively harness S&T and knowledge. In 2006, they renewed their pledge to invest 1% of their national GDPs to S&T.

The Comprehensive Africa Agriculture Development Programme (CAADP), which is the continent's policy framework for leveraging agriculture for Africa's economic transformation, recognises the strategic value of knowledge to its mission and has accordingly devoted one of its three strategic thrusts to knowledge and knowledge management.

In this paper I discuss the actions Africa should consider as it seeks to take advantage of S&T as one of the key levers of its development agenda. To present my points I refer to S&T in the agricultural domain because as I have pointed out above, it is through improving agricultural performance that Africa stands to make the biggest gains in increasing food security and poverty reduction.

Underinvestment in S&T persists despite high returns

Studies by the International Food Policy Research Institute (IFPRI) have shown that returns to investments in developing countries' own national agricultural research systems regularly outperform investments in other sectors, such as transport infrastructure and education (see

figure 1). Intriguingly, the high returns have not translated into increased investment in research and development.

Underinvestment is the main reason explaining the poor state of S&T in Africa (UNESCO, 2010). Underinvestment persists despite S&T's recognition as a driver for growth. It generally cuts across the generation, delivery and application of knowledge, that is, research, extension and education.

An analysis of 24 national poverty reductions strategy papers carried out by the InterAcademy Council study panel in 2004 found that only 4 PSRPs cited agricultural research as a priority while half of them indicated that the technologies required to increase productivity existed and what was needed was their delivery to farmers (IAC, 2004).

This reasoning discounted the fact that technologies take a long time to develop and that the research that should be undertaken now is research aimed at addressing problems and opportunities that will manifest several years or decades ahead.

	China	*India*	*Thailand*	*Vietnam*	*Uganda*
Ranking of Returns to Agricultural Production					
Agriculture R&D	1	1	1	1	1
Irrigation	5	4	5	4	
Education	2	3	3	3	3
Roads	3	2	4	2	2
Telecommunications	4				
Electricity	6	8	2		
Health		7			4
Soil and Water Conservation		6			
Anti-Poverty Programs		5			
Ranking of Returns in Poverty Reduction					
Agriculture R&D	2	2	2	3	1
Irrigation	6	7	5	4	
Education	1	3	4	1	3
Roads	3	1	3	2	2
Telecommunications	5				
Electricity	4	8	1		
Health		6			4
Soil and Water Conservation		5			
Anti-Poverty Programs	7	4			

Figure 1. Ranking returns on investment in Agricultural R&D (Source:

The underinvestment in S&T despite evidence of high returns, suggests that either investment decisions do consider available evidence, i.e. there are other more important considerations or those responsible for make the investment decisions are oblivious of the evidence. Whatever

the case, the current state-of-affairs highlights the need for increased advocacy and engagement with the policy makers responsible for making such investment decisions...

In conducting this advocacy the choice of messenger(s) is/are as important as the message. In many countries the private sector including agribusiness and the producers wield considerable political influence, partly because of their numbers (and therefore votes) and partly because they are well organised. Since these two groups are primary beneficiaries of S&T, it can be presumed that they are amenable to joining hands with scientists to advocate for S&T. The innovation in mobilising their support and assuring that it delivers the intended effect lies in the institutional arrangements that enable their effective and sustainable engagement. I submit that the relevant institutional arrangement is the national S&T innovation platforms

The increasing complexity of the context served by S&T

Modern agriculture operates within a complex and dynamic context and is multifunctional in nature. That is, it does not aim to maximise one function such a yield, but multiple objectives including, food security, nutrition and safety, natural resource bio energy. These objectives are pursued in a context where: the demand for food in Africa is projected to double over the next 40 years, a nutrition transition is emerging, the production environment is becoming increasingly harsher and inequality is deepening.

Under these conditions it will be important for agricultural S&T to embrace system approaches taking advantage of sciences outside the conventional agricultural domain such as nutrition, health, energy and engineering. To highlight the complexity that current agricultural S&T must contend with, it should develop solutions for the future agriculture that will be required to produce significantly more food on less land, with less water, using less energy, fertilizer and pesticide whilst not increasing greenhouse gas emissions; reduce the amount of pre- and post-harvest losses while producing nutritious and safe food.

The complexity of the context in itself shows that science-based solutions are now needed more than ever before. Science and technology on its own cannot deliver the required changes. It should be appropriately embedded within the broader concept of innovation that considers the profitable utilisation of technology.

Evidence assembled by the Forum for Agricultural Research in Africa (FARA) and partners testing the viability and efficiency of an innovation systems approach for the generation, delivery and utilisation of agricultural knowledge shows that the innovation systems approach offers much greater benefits (FARA, 2012).

How can Africa harness S&T to power its development?

I list four courses of action that I consider to be the most important measures Africa should undertake or reinforce to harness the power of S&T to drive its development agenda.

1. Strengthen policy to support the generation, delivery and application of relevant knowledge needed to achieve development. The policy includes making the required investments to support S&T (for example in research, extension, education, finance, infrastructure), putting in place the necessary institutional arrangements (for example the innovation platform), promoting the necessary mind-set changes (for example reliance on evidence to inform decision making).

   The policy should be well articulated and it should adopt a long term view. A tendency that has undermined the effectiveness of S&T in African is having a short term view. More often than not such a view is associated with external funding which is typically of a short term nature.

2. Realising the potential of S&T is conditional on availability of human and institutional capacities responsible for its generation, delivery and application. This point is further reinforced in 3 below.
3. S&T especially the generation of knowledge (research) is a capital intensive undertaking. Africa happens to be fragmented into numerous countries many with similar agricultural ecologies. To build critical mass and reduce duplication, countries should engage in collective action to pool human and other resources around regional centres of excellence that will be equipped with the capacity to perform functions that individual countries may not be able to readily afford. The existing agricultural research and development architecture comprising NARIS at national level, SROs at sub regional level and FARA at the continental level can be harnessed to support the operationalisation of these centres. Deeping regional integration as well as north-

south and south-south partnerships may also be harnessed to strengthen collective action.

4. It is essential that Africa articulates an agenda for agricultural S&T which sets out the knowledge Africa requires achieving its development objectives and how that knowledge will be generated, delivered and applied. That agenda will also serve as a tool for the coordination of S&T initiatives by assuring that the various priority areas of the science agenda are given attention. FARA is coordinating an initiative to develop a science agenda that will be launched by AU Heads of state and governments at their summit in January 2014.

Conclusions

S&T has had a dramatic impact on quality of life for virtually everybody. However, it has benefitted the wealthier people much more than the poor and vulnerable and has in some instances exacerbated inequality. Moving ahead we should assure that S&T strategies are pro-poor.

The changes needed to re-orient S&T to make it more effective in driving development call for strong S&T leadership at all levels. Thus leadership should be a key consideration in capacity strengthening.

Last but not least, Africa should embrace forward thinking, anticipating what the future is likely to bring up in terms of challenges and opportunities and then using that knowledge to work towards the future it wants and determine the S&T required realising that future.

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SECTION I:

AGRICULTURAL SCIENCES

1.0 The growth response of coffee plants to organic manure, inorganic fertilizers and integrated soil fertility management under different irrigation levels

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ABSTRACT

A study was carried out to determine effects of organic, inorganic fertilizers and integrated soil fertility management and irrigation levels (1000ml, 750ml and 500ml per planting station) on coffee growth. There were no significant differences ($p>0.05$) in girth, leaves and primaries due to the different soil fertility management options. Significant differences ($p<0.05$) due to soil nutrient sources were observed in coffee height where inorganic fertilizer treatment resulted in tallest coffee plants (47.4cm) and integrated soil fertility having the shortest coffee trees (42.8cm) after one year. The highest irrigation level of 1000ml had the tallest plants with thickest stems while the lowest level had the shortest and thinnest plants ($p<0.05$). No significant differences were observed in number of leaves and primaries due to irrigation treatments. Results indicate that inorganic fertilizers are most effective at high irrigation levels while organic manure perform better than inorganic fertilizers under low irrigation water levels.

Key Words: coffee plants, organic manure, irrigation, fertilizers, soil fertility.

INTRODUCTION

Soil fertility management and water supply are important for successful crop production in all agricultural commodities. The use of inorganic fertilizers has been a significant contributor to increased crop productivity since the green revolution, and has resulted in reduced use of organic nutrient sources that farmers have relied on for centuries (1). The quality of fertilizers, their costs and yield contribution are as variable as their sources. The most common sources of organic manure used in crop production are livestock dung, composted and green crop residues, farmyard matter and organic manure from natural systems and material production systems (1; 2).

The need for renewable, locally available and cheaper options for supplying nutrient to crops is increasingly becoming important because of the need for sustainable agriculture (3-5). With

growing demands for sustainably produced agricultural produce for environmental, social and food safety reasons, the use and recycling of organic matter is becoming inevitable, particularly for export market depended commodities such as coffee.

Sustainable agriculture is a production process and farm management system that has positive economic, ecological and social benefits in the short and long term (6). The levels of sustainability varies on a sliding scale from the strict organic farming methods that demand perfect quality of the production process and the environment to general guidelines and codes of conduct on various aspects of the expectations of the production system (6; 7). Use of organic soil fertility options is among the key attributes of sustainable agriculture. Maintaining physical, chemical and biological soil properties for plant growth and environmental efficiency requires the input of organic matter that is decomposed into nutrients and used up by plants. Sustainable production is becoming a necessity for coffee sectors to remain competitive in the global trade against oversupply and price fluctuations that in some years result in coffee price crisis.

Reliance on inorganic fertilizers may not be sustainable in the long term given that soils may lose microorganisms, become acidic and having unstable aggregates leading to erosion and general degradation, and this may explain yield decline with time despite consistent use of inorganic fertilizers (5). Studies on the potential of using organic nutrient sources in coffee production identified cattle manure as the most promising (2; 8; 9) while recycling coffee wastes such as pulp and prunings as direct inputs or in combination with green manures and live mulch in nutrient management were effective in promoting coffee growth and yield and also economically viable (10).

On the other hand, some studies have shown that organic manures are very important for maintaining soil organic matter and supplying nutrients to the coffee systems but may not be enough for balanced plant nutrient flows and for achieving profitable yield levels (11). This is because the maximum N obtainable from common organic manures is less than 10%, P less than 2% and K and less than 10% of dry matter compared with high nutrient outflows of up to 105kg ha^{-1} of N, 13kg ha^{-1} of P and 107kg ha^{-1} of K to achieve yield levels of 1t ha^{-1} per year resulting in serious negative nutrient balances (12; 13). Given that the negative nutrient balance from use of organic manures is only apparent in yielding coffee, it maybe that organic manures or at least integrated are able to provide a positive nutrient balance when the coffee has not reached bearing age.

Water supply is increasingly becoming important in coffee production given the unreliable rainfalls and frequent droughts that affect growth, yield and quality of coffee (14; 15). According to Coffee

Management Services (16), irrigation is an expensive management practice because it involves pumping costs, labour and other equipment requirements. This is despite the fact that soil water is important for keeping plant nutrients in solution, maintain soil microorganisms, and for root and shoot development and functioning all of which have a bearing on production levels and quality (11). Studies on irrigation levels and N rates of pomegranate and coffee showed that the high rates of N are effective when there is minimum water depletion (17; 18). This indicates that with limited water supply such as in cases of drought, N and probably other nutrients are not easily available from inorganic sources of soil nutrients.

Soil organic matter plays an important role in moisture retention and therefore the use of organic manures is considered as a climate change adaptation strategy. Soil moisture is important for the decomposition of organic matter and making nutrients from both organic and inorganic fertilizers available to the plant (19). Irrigation water management is very critical in coffee production. Excessive irrigation is costly and moisture stress results in dieback, wilting and opportunistic disease and pest attacks, resulting in reduced production in both cases. Depending on the timing, moisture stress can also result in floral abortion, which results in reduced yields. The interaction between sources of nutrients and irrigation levels is therefore very important especially in the context of reducing production costs and adapting to climate change in the coffee sector. Soil fertility management and irrigation water supply are therefore two important management functions in coffee production.

OBJECTIVES

The objectives of this study were to establish the growth effects of different soil fertility management options and irrigation levels on coffee vegetative growth, which has direct implications to coffee yield and quality. Additionally, the synergistic effects of soil fertility management and irrigation levels were also investigated in order to identify if organic soil fertility management can sustain coffee growth when water supply is low by improving soil moisture conservation and water use efficiency. This information is important in building a productive, sustainable and robust coffee production system under challenges of environmental accounting and reduced rainfalls in rain fed systems due to climate change.

METHODOLOGY

Study Sites and Treatments

The experiment was carried out at Coffee Research Institute, Chipinge, Zimbabwe ($32^0 39^/$W, $20^0 13^/$ S and altitude 1100m above sea level). Healthy coffee seedlings (variety Catimor 129) that were

six months old were transplanted into five litre earthen pots. The seedlings were stripped of their initial soil and then planted in media that contained the different soil fertility treatments. The treatments consisted of organic, integrated and inorganic fertility management options.

The organic manure treatment contained composted humus obtained from under a forest after clearing fresh litter. Sieved 3kg of humus were mixed thoroughly with 2kg of soil media then the coffee seedlings planted. For integrated fertility option, 1½ kg of humus were mixed with soil humus and 25g of inorganic fertilizer (15:5:20 NPK) mixed in the soil before planting seedlings. The inorganic fertilizer treatment had 50g of inorganic fertilizer mixed with soil before planting coffee seedlings in the soil media. The media which was mixed with the fertility treatments was topsoil obtained from an old fallow. The soils at the institute are orthoferallitic according to the Zimbabwe Classification System, derived from UmkondoQuartzites&shales and consist of deep, fine-to-medium grained sandy loams on the surface (20).

Trial Set Up

The fertilizer application rates for the inorganic and integrated fertility management treatment were calculated from the published rates of inorganic fertilizer recommendations for young coffee in the field which are 1t ha^{-1} per year (21). At a plant spacing of 3m x 1.5, a plant population of 4450 plants ha^{-1} will be obtained using double covas and therefore half the rate per plant will give 50g per planting station. All soil fertility treatment applications were repeated after 6 months. Three water levels were used as irrigation treatments. These were a high rate with 1000ml, a moderate rate with 750ml and low rate with 500ml. All the water treatments were applied bi-weekly.

Measurements and data analysis

Measurements were taken on a bi-weekly interval on counts of number of leaves (recorded for the first 6 months), girth measured at 5cm from the surface using a Vernier callipers, height measured to apex leaf using a metre rule and counts of number of primaries for one year. Counts of number of leaves and number of primaries were log transformed before statistical analysis. Repeated Measurements Analysis of Variance was used to determine the significance of the variance between treatments on the data recorded over time (Mean) and Analysis of Variance was used for analysis of final recording of data (Final) in Genstat 14 software (VSNI, 2011) and linear regression and analysis of covariance were done in Excel and R.

RESULTS

Effects of soil fertility on coffee growth

Effect of fertility option on coffee biometric characteristics

Inorganic fertilizer produced the tallest coffee seedlings ($p<0.05$) with a final height of 124.8cm. Combining inorganic and organic fertilizers performed better than just organic fertilizers alone in both the mean height and the final height of the coffee seedlings. Organic manure resulted in the shortest coffee plants with a mean height of 42.8cm and a final height of 78.6cm (Figure 1). Mean and final coffee stem thickness did not significantly respond ($p>0.05$) to soil fertility treatments (Figure 2). There were no significant differences ($p>0.05$) due to soil fertility treatments in mean and final number of leaves and number of primaries (Table 1).

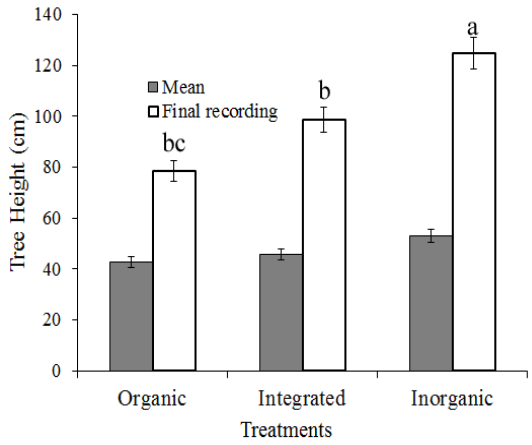

Figure 1: Effect of soil fertility options on coffee height (treatments with different letters significantly different after Tukey test ($p<0.05$))

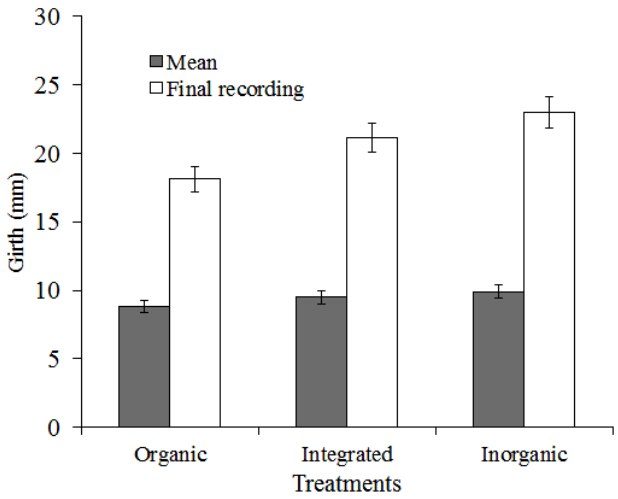

Figure 2: Effect of soil fertility option on coffee girth

Table 1: Effects of treatment on number of leaves and branches

Treatment	Number of leaves		Number of primaries	
	Mean	Final	Mean	Final
Inorganic	14.9	19.8	8.4	17.1
Integrated	14.3	18.7	8.7	18.2
Organic	15.5	20.8	8.9	17.7
P	0.364	0.282	0.082	0.115

Effects of soil fertility options on the growth partitioning

There was evidence in proportional growth of girth, number of primaries and height when coffee plants are under organic manure ($p<0.05$, Table 2). This partitioning was not apparent under inorganic fertilizers as none of the relationships were neither strong nor significant. The strongest proportional growth was between height and girth under organic manure ($r^2=0.77$, $p<0.05$). Under integrated soil fertility management, the relationship between girth and number of primaries was significant ($r^2=0.46$, $p<0.05$). Examination of the relationships indicated that under inorganic fertilizers, there is more growth of primaries at the expense of girth and height, and more height at the expense of girth (Figure 3g-h).

Table 2: Growth partitioning due to soil fertility treatments

Treatment	Factors	r^2	*P*
Organic	Primaries and height	0.52	0.0293*
	Girth and primaries	0.37	0.0848
	Height and girth	0.77	0.0018**
Integrated	Primaries and height	0.058	0.5327
	Girth and primaries	0.46	0.0453*
	Height and girth	0.004	0.8677
Inorganic	Primaries and height	0.23	0.1913
	Girth and primaries	0.16	0.2801
	Height and girth	0.18	0.2589

Effects of soil fertility options on the growth patterns

Coffee plant girth, number of leaves, height and number of primaries showed a very strong (r^2>0.9) linear growth over time (Table 3). Analysis of covariance showed that there was no significant differences between the slopes of girth, number of leaves and number of primaries (p>0.05) between organic, integrated and inorganic fertilizer options over time.

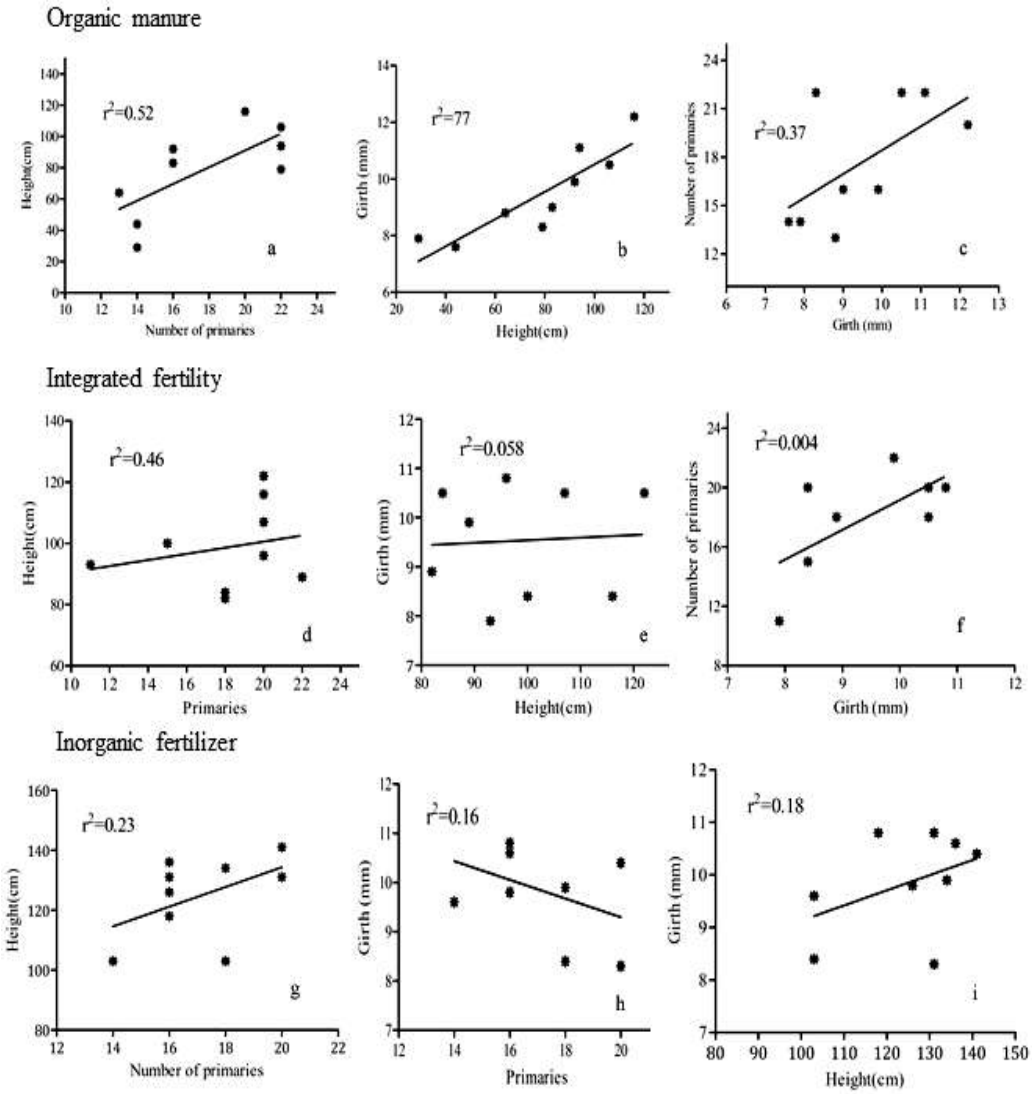

Figure 3: Coffee growth partitioning between number of primaries, height and girth under different fertility options

Table 3: Growth functions for each of the treatments for girth, leaves, primaries and height

Attribute	Treatment	R^2	*p*	Function
Girth	Organic	0.98	<0.001	y=0.15x+2.4
	Integrated	0.98	<0.001	y=0.15x+2.5
	Inorganic	0.99	<0.001	y=0.16x+2.5
Height	Organic	0.96	<0.001	y=0.79x+13.1
	Integrated	0.95	<0.001	y=0.68x+15.2
	Inorganic	0.94	<0.001	y=0.85x+13.8
Leaves	Organic	0.97	<0.001	y=0.45x+8.1
	Integrated	0.96	<0.001	y=0.46x+7.4
	Inorganic	0.97	<0.001	y=0.51x+7.9
Primaries	Organic	0.98	<0.001	y=0.23x-1.7
	Integrated	0.96	<0.001	y=0.23x-1.4
	Inorganic	0.93	<0.001	y=0.24x-1.6

Effect of water levels on coffee growth

Effect of water levels on biometric characteristics

The young coffee plants significantly responded ($p<0.05$) to irrigation water amounts in terms of height and girth. Coffee plants were tallest (118.6cm) and had thickest plant stems (10.2mm) when supplied the more irrigation water levels and shortest (89.9cm) and thinnest (8.8mm) under the lowest irrigation amounts (Fig 3a and 3b). In terms of number of leaves and number of primaries, there were no significant differences ($p>0.05$) due to different irrigation levels (figure 3c and 3d). The coffee plants developed comparable number of primaries under lower and intermediate irrigation levels and these were lower than the number that developed under the highest irrigation level (Fig 3c). The highest irrigation level had the highest number of leaves while more leaves developed under lowest irrigation rate than under the intermediate levels.

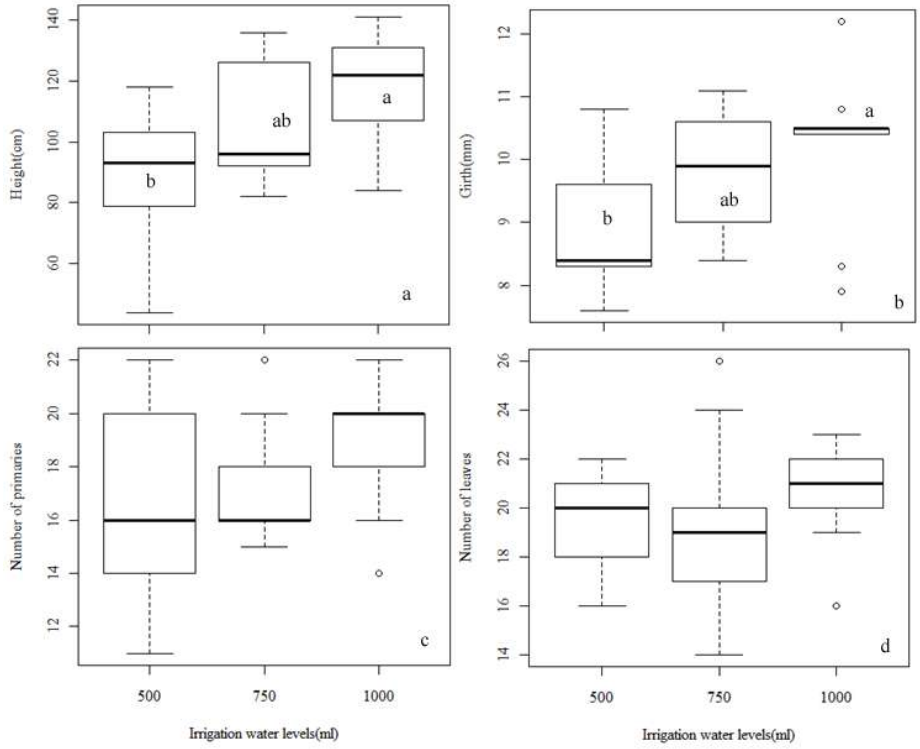

Figure 4: Growth response of young coffee to different irrigation levels

Effect of water levels on growth partitioning

There was no significant partitioning in growth of girth, number of primaries and height when coffee plants are irrigated with a high, medium and low amounts ($p>0.05$, Table 4). Growth partitioning was only significantly proportional between girth and number of primaries when coffee plants were provided with medium levels of irrigation ($r^2=0.45$, $p<0.05$, Table 4).

Table 4: Growth partitioning due to irrigation water levels

Treatment	Factors	r^2	*p*
1000ml	Primaries and height	0.057	0.5347
	Girth and primaries	0.034	0.6356
	Height and girth	0.285	0.1391
750ml	Primaries and height	0.044	0.5891
	Girth and primaries	0.449	0.0484*
	Height and girth	0.095	0.4194
500ml	Primaries and height	0.036	0.6082
	Girth and primaries	0.187	0.2448
	Height and girth	0.099	0.4086

Interaction between soil fertility options and water levels

The interaction between nutrient source and irrigation water level was only significant ($p<0.05$) in coffee height where the highest irrigation rate (1000ml) under inorganic fertilizer had the tallest coffee plants. The results indicate that coffee plants grow better under inorganic fertilizers when there is more irrigation water supply as shown by height, girth and number of primaries (Figure 5-7). However, more growth is achieved under low irrigation level when organic manure is used for soil fertility management (Figure 5-7). Taller plants and thicker stems of coffee plants were realized under organic manure while integrated fertility had more primaries and leaves than the inorganic and organic treatments.

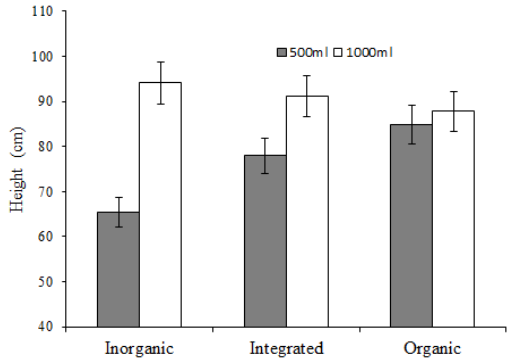

Figure 5: Coffee plant height under low and high water levels

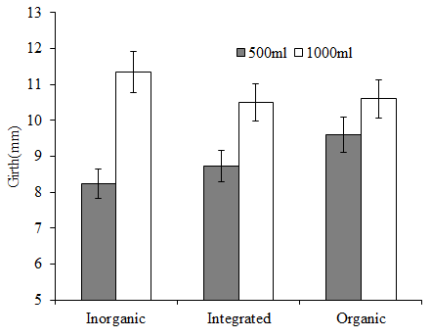

Figure 6: Coffee girth under low and high water levels

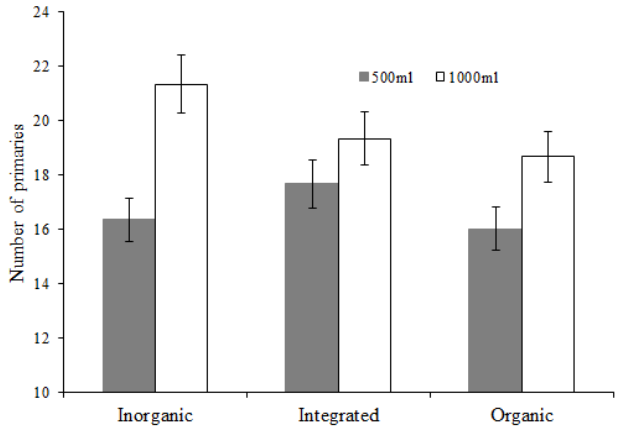

Figure 7: Number of primaries under low and high water levels

DISCUSSION

The readily available N from the inorganic fertilizer was fundamental in producing taller coffee plants than the organic manure which need time to decompose and produce the required nutrients. Thus, as the organic manure was decomposing, the plants were already benefiting from the inorganic fertilizers resulting in the taller coffee plants. The height benefits could not be translated into benefits on girth, as stem thickness, unlike apical growth, is promoted by availability of P

which tends to be more abundant in organic nutrient sources, making the organic treatment and the integrated fertility option as competitive as inorganic fertilizers (18).

Using organic manure and integrating it with inorganic fertilizer managed to produce a growth pattern (as measured through leaf and primary development) that is comparable to that of recommended levels of inorganic fertilizers. The competitive performance of integrated fertilizer to inorganic fertilizers was also reported by Nyalemegbe who concluded that combining poultry manure with inorganic fertilizers resulted in similar yields in rice as those obtained from using inorganic fertilizers alone. In addition, composted humus could add to other sources of organic soil nutrients that could be combined with inorganic fertilizers such as composted coffee pulp, cattle manure, poultry manure, sugarcane filter cake and crop residues (10; 12). Humus has the added advantage that it can be locally available from forest patches and this underlines the importance of managing trees on or around coffee farms for nutrient cycling and humus input (11; 22; 23).

Although the results showed that coffee grows more when applied with inorganic fertilizers, the growth partitioning showed that there is no balanced growth under this fertilizer regime. Organic manures had the most significant proportional growth indicating that the organic sources of nutrients are able to provide a balanced supply of nutrients. This is unlike inorganic fertilizers that supply only the nutrients in their formulation which may favour growth of some specific parts of the plant (2). For example, while the N may support growth of new leaves and height, P, which is the least of the proportion in the fertilizers used in this study, will be important for the development of the woody parts of the plants (3; 11). The balanced developments of both vegetative and woody parts of the plant as provided by organic manure are very important for plants such as coffee whose vegetative parts such as leaves are not harvested. It was surprising that there was no significant growth partitioning due to different levels of irrigation. It is expected that under water stress, the coffee plants will prioritize growth and maintenance of roots and other woody parts of the plant at the expense of vegetative growth of leaves and height (14; 15).

The less pronounced growth after the 26th week signifies the response of the coffee plant to abiotic factors particularly temperature during the winter months. The 26th week coincides with the start of winter in the study area and this indicates that although coffee is a perennial plant, plant growth is more pronounced and accelerated in the warm summer months than in cold winters. The coffee plant may also be changing priorities for nutrient allocation from primary growth to fruiting in winter, resulting in reduced vegetative growth. Logan & Biscoe (21) reported that the coffee plant continually makes new growth the whole year round but it is important to note that the vigour is reduced during winter months as indicated by the results. This reduced growth is apparent even in the absence of both soil fertility and water deficit and thus, it is important to make sure that the

coffee plant has adequate water and soil nutrients to avoid premature leaf senescence, dieback and other effects of water and nutrient shortages at the time when they are most required for supporting fruit development.

The coffee plant responds to increasing the amount of irrigation as indicated by the responses in girth and height. However, in terms of number of primaries and number of leaves, there were no significant responses to increasing water levels and this could be attributed to the fact that the coffee plant has inherent drought tolerance habits that enable it to survive and develop under low water levels. This is explained by Hess et al., (24) who observed that stoma of coffee are very sensitive to light and in sun-coffee systems, they close even in abundance of water.

Since the highest water supply level had the tallest and thickest stems, it shows that the young coffee plants significantly responds to increased irrigation. This reinforces the suggestion by Logan & Biscoe (21) that in coffee production, irrigation can be the deciding factor on success. It is however not clear from this study how the different water levels applied are related to crop requirements and actual water use efficiency. The water use of crops increases under increased water supply in as much as water loss through transpiration also increases(18).

The positive interaction between irrigation levels and organic sources on height and the improved growth perfomance of coffee plants under low water supply levels point to the importance of organic manure in regulating soil water for plant use. Ibrahim & El-Samad(18) also reported that water use significantly decreases with increasing amount of organic manure in the soil. The increased efficiency in growth of coffee plants under organic and integrated soil fertility under low irrigation could be due to the positive effects of organic manure on soil physical and chemical properties such as soil structure, texture, porosity and gradual nutrient release are significantly improved by addition of organic manure which resultantly improves the soil water holding capacity (2; 11). However, the availability of nutrients such as P and K from organic sources is significantly affected by availability of water in the soil and thus sufficient water should always be available for immobilising nutrients from organic sources (3; 18; 25).

CONCLUSIONS

The results indicated that organic and integrated nutrient sources are able to provide sufficient nutrients for healthy coffee growth. The use of integrated fertility management could be the most attractive option given that it reduces on both costs of inorganic fertilizers and also on quantities of composts required for efficient coffee growth. Higher levels of irrigation are required for promoting growth in coffee but exact crop water requirements for young coffee need to be established to avoid oversupplying or undersupplying irrigation water. The use of organic manure improves the growth

performance of young coffee under low water levels while application of inorganic fertilizers results in more growth at higher water levels. Further studies are required to determine if these trends are carried further to coffee yield and quality.

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Declaration

No part of this work has been published elsewhere.

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Evaluation of promising spring bread wheat (*Triticumaestivum* L.) breeding lines under irrigated multi-environment conditions in Zimbabwe

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ABSTRACT

The trials were set up to identify breeding lines that combine high yields with stability across environments via GGE bi-plot methodology. In addition, we intended to identify the best test environments. The studies were conducted across seven locations during the 2008, 2010 and 2011 wheat growing seasons. The experiments were laid out in a RCBD with three replications. Grain yield and agronomic traits were analyzed in Genstat Discovery Version 14 software. The GGE bi-plot in Genstat Discovery Version 14 was used to identify best test environments, stable and high yielding genotypes across locations. Environment, genotype and genotype x environment interaction main effects were highly significant ($P < 0.001$) for grain yield. Environment main effect accounted for 95.22% of the total variation. S02147-7H-ON-2H-ON, INSIZA, S02006-5H-ON-1H-ON and S01214-3H-ON-2H-ONwere high yielding and stable across three years and could be proposed for release. Mutare was the best test environment.

Key words:Stability, *Triticumaestivum*L., multi environment trials, GGE bi-plot

Abbreviations: GGE; Genotype main effect plus genotype × environment interaction; RCBD: Randomised Complete Block Design;

INTRODUCTION

Wheat (*Triticumaestivum* L.) is the second widely consumed cereal after maize in Zimbabwe. The crop is produced by both smallholder and large scale commercial farmers who are located in different agro-ecological regions of the country. Wheat in Zimbabwe is produced in the cool dry winter months (May

– October) and sustained through irrigation. The identification of high yielding, adaptable and stable wheat genotypes across all the wheat producing environments in

Zimbabwe has been a continued challenge to plant breeders. Developing stable, widely adapted and high yielding wheat genotypes that can be grown under irrigation are the major objectives of wheat breeding programs in Zimbabwe. Breeding for broad (wider) adaptation involves evaluating germplasm under multi-environmental trials over a period of time. Our approach as a breeding programme is wide adaptation considering that Zimbabwe is a small country. Therefore, trying to breed for each small production environment would become very expensive. Multi-environment yield trials are usually performed in the final stages of genotype evaluation in a breeding programme. This permits selection of superior and stable genotypes that could be recommended for release and wider cultivation. For the general cultivation of any crop plant, testing at multi-environments is very important to ensure that the selected cultivars have acceptable performance in variable environments within the target region (1). Therefore, the identification and release of wheat genotypes with consistent performance under multi-environment conditions will lead to stability in production. The breeding of new improved wheat cultivars will increase wheat productivity in Zimbabwe which will ultimately improve the livelihoods of millions of people.

Several stability statistics have been proposed and employed to identify best performing lines across locations. (2) proposed the use of GGE bi-plots that allows visual examination of the Genotype Environment (GE) interaction pattern of multi-environment trial (MET) data. GGE bi-plot refers to the genotype main effect (G) and the genotype x environment interaction (GE), which are the two sources of variation that are relevant to cultivar evaluation. GGE bi-plots are useful tools that aid plant breeders and agronomists in identifying stable and adaptable wheat genotypes with high yield performance. However, genotype x environment interactions (GEI) are the biggest challenges to plant breeders and agronomists as they result in differential response of cultivars across diverse environments which reduce the usefulness of genotypes by confounding their yield performance. In general, GE interactions are considered a hindrance to crop improvement in a target region (3). Plant breeders therefore evaluate genotypes in multi-environment trials inclusive of favourable as well as unfavourable conditions to address the GEI issue. (4) explained that the genotype environment interaction can either be exploited by selecting superior genotypes for each specific target environment or avoided by selecting widely adapted and stable genotypes across wide range of environments. Wheat grain yield is highly influenced by production environments and this further explains the need to evaluate wheat genotypes under multi-environment conditions in order to target the best for varietal release. Plant breeders often determine stability of high yielding genotypes across environments before recommending a stable cultivar for release (5).

According to the GGE biplots, an ideal genotype combines high mean yield (large principal component (PC1) score) with high stability (low PC2 score) performance. Similarly, an ideal test environment should have a large PC1 score (more discriminating of the genotypes in terms of the genotypic main effect) and small (absolute) PC2 score (more representative of the overall environment) (6). In multi-environment evaluation, scientists look out for an 'ideal' environment where maximum information can be obtained at the minimal cost (both human and other resource) from the evaluation. The ideal test environment should be most discriminating (informative) and most representative. This information is useful when making recommendations for variety production. In addition, ideal production environment informs breeding programmes on locations where variety discrimination can be achieved.

Temporal instability of a genotype has a negative effect on farmers' income and, in the case of staple crops, contributes to food insecurity at national and household level (7, 8). High yield stability refers to a genotype's ability to perform consistently, whether at high or low yield level, across a wide range of environments (9). Adaptability is the ability of the genotype to be high yielding with respect to a given environment or conditions to which it is adapted (10, -8). The wheat growing environments in Zimbabwe are diverse because of a great deal of variation in soil types, temperatures and altitude from the highveld (> 1200 meters above sea level) to the lowveld (< 800 meters above sea level). Therefore, the evaluationof wheat genotypes across multi-environments and over several years is needed to identify spatially and temporally stable genotypes that could be recommended for release.

The main objectives of the study were to (i) identify wheat breeding lines that combine high yields with stability across environments using GGE bi-plot statistical tool (ii) to identify best wheat test environments (representative and discriminating environments) in Zimbabwe, and (iii) to cluster wheat production areas into mega-environments.

METHODOLOGY

Experimental data

The study was conducted in 2008, 2010 and 2011 at seven on-station locations in Zimbabwe during the main wheat cropping seasons (May – October) under irrigated conditions. The sites included Gwebi Variety Testing Center (GVTC), Harare Research Station, Agricultural Research Trust farm (ART farm), Panmure Experimental Station, Chisumbanje Experimental Station, Save Valley Experimental Station and Mutare (Sisal farm). Sisal farm was considered an on-station location because of the crop husbandry practices followed at the farm and the involvement of the wheat research team in trial management and harvesting processes. Sisal farm has been hosting Crop Breeding Institute's and Seed-co's (private seed company) wheat variety evaluation trials for many years. More details on the testing sites and the agro-ecological characteristics for all the locations used are shown in **Table 1.** A total of

fourteen bread wheat genotypes (eight check cultivars, six advanced breeding lines) were tested over three seasons. The promising breeding lines were from the Crop Breeding Institute and the check cultivars were from Seed-co, Pannar Seed Company and Crop Breeding Institute. Smart, Insiza and Stallion are high yielding and stable cultivars which are widely adapted across locations. This explains the reasons whythey were chosen as check varieties.

Table 1: On-station sites of spring wheat yield trials conducted in 2008, 2010 and 2011

Code	Location	Soil Properties	Latitude	Longitude	Altitude (masl)
E1	Harare	Clay	-18.11S	31E	1506
E2	GVTC	MG/SCL	-17.69S	30E	1449
E3	Panmure	MG/SCL	-17.28S	31E	892
E4	Sisal	Clay	-19.78S	32E	1053
E5	Save Valley	Clay	-20.48S	33E	450
E6	ARTFARM	MG/SCL	-17.70S	31E	1532
E7	Chisumbanje	Basalt	-20.80S	32E	413

More details on genotypes and the information on their breeding history were highlighted (**Table 2)**. The experiment was laid out in a randomized complete block design with three replications. The plot size was 8 m^2 with 10 rows of 4 m long with spacing of 0.2 m between rows across the three seasons. The seeding rate was 110 kg/ha for all environments. Compound D was applied at planting at a rate of 300 kg/ha. Ammonium nitrate fertilizer application was 200 kg/ha at both tillering and stem elongation stages. A plot combine harvester was used to harvest the 4 m x 6 row plots. Grain yield data in kg $plot^{-1}$ was taken from six central rows in plots and converted in to tons $hectare^{-1}$ at 12.5% moisture content.

Table 2:Code and pedigree of 14 wheat genotypes used at on-station

Cultivars	Status	Pedigree	Origin
G1	Breeding line	S01214-3H-ON-2H-ON	CBI
G8	Breeding line	S02009-8H-ON-3H-ON	CBI
G9	Breeding line	F02048[y]	CIMMYT
G12	Breeding line	S02147-7H-ON-3H-ON	CBI
G20	Breeding line	S02006-5H-ON-1H-ON	CBI
G24	Breeding line	S02147-2H-0N-2H-ON	CBI
G7 (INSIZA)	Check Cultivar	S86073-5H-ON-3H-1H-OG	CBI
G10 (Kana)	Check Cultivar	S89067-OH-OG-7H-OG	CBI
G19 (Kame)	Check Cultivar	S95063-6H-ON-1C-OG-1H-OG	CBI
G21	Check Cultivar	SMART[p]	SEED-CO
G23	Check Cultivar	PAN 3492[p]	SEED-CO
G25	Check Cultivar	SHIELD[p]	SEED-CO
G15	Check Cultivar	STALLION[p]	SEED-CO
G5 (Dande)	Check Cultivar	S92011-3H-ON-1H-ON	CBI

Notes

[p]: private seed company, pedigree not known

[y]: International Maize and Wheat Improvement Center (CIMMYT) bred line

CBI: Crop Breeding Institute

Analysis of Variance

Grain yield data was analysed with Genstat Discovery 14th Edition software to determine the G, E and GEI effects. GGE bi-plots were also estimated in Genstat Discovery 14th Edition.

GGE bi-plot analysis

To determine grain yield stability and identify superior, well adapted genotypes across locations, (GGE) bi-plots were conducted using GGE bi-plot software (11, 12). The GGE bi-plot methodology is composed of two concepts, the bi-plot concept and the GGE concept (6). The main genotype effect (G) and the genotype x environment interaction effect (GE) is shown by the GGE bi-plot. The GGE bi-plot shows the first 2 principal components (PC1 and PC2) derived from subjecting environment centered yield data to singular value decomposition (6). PC1 scores of both genotypes and environments are then plotted against their respective PC2 scores. The GGE bi-plot has been widely used to determine grain yield stability and identify superior, adapted genotypes in multi-location trials (13). Comparisons among genotypes with a reference genotype (ideal genotype) were made using the GGE bi-plot. The ideal genotype will be stable and have the highest average mean value among the genotypes. Correlation coefficients among environments were also conducted. The symmetric scaling was used in visualizing which won where pattern of multi environment yield trial (14).

Discrimination ability, representativeness & relationships among test environments

The GGE bi-plot analysis was used to examine relationships among environments and to compare among a set of environments with discriminating ability & representativeness. The correlation between two environments can be approximated by the cosine of the angle between the vectors of two environments. Two environments are positively or negatively correlated if the angles between their vectors are less than 90° or more than 90° (5) respectively. A vector was used to connect each environment to the bi-plot origin so as to show the discriminating ability of test environments. The environments with longer vectors are more discriminative of the genotypes; short vectors are less discriminative (5). An environment with a small angle with the average environment axis is more representative of other test environments. Ideal test environments should have near zero PC2 scores (more representative of the average environment) (6). Discriminating ability refers to a location's ability to maximize the variance among genotypes in a study (15). Thus an ideal location should be highly differentiating of the genotypes and representative of the target location. The GGE bi-plot way of measuring representativeness is to define an average location and use it as a reference or benchmark (11). The identification of an ideal test location on the basis of discriminating ability and representativeness implies that selections made at that site would have the highest probability of representing truly superior genotypes that perform well in all locations in the growing region (16).

The test environments which are consistently non-discriminating provide little information on the genotype differences (12).

Genotypic performance, adaptability and stability

The cosine of the angle between the genotype and a specific environment and the length of the vectors determines the performance of a genotype in an environment. According to (12), genotypes are better than average if the angle between its vector and the environment's vector is less than 90°, poor than average if the angle is greater than 90°. An ideal genotype should be stable (have PC2 scores near zero) and adaptable (have high PC1 scores). Thus a genotype further from the biplot origin on either side of the stability line represents relatively lower stability.

RESULTS AND DISCUSSION

Anova and mean yield performance

The analysis of variance at 5% significance level showed that genotypes (G), environments (E) and genotype x environment interactions (GEI) were highly significant ($P < 0.001$) on yield and accounted for 2.03%, 95.22% and 2.75% of the total sum of squares, respectively (**Table 3**). The yielding ability of the wheat genotypes was influenced by environment. Similar results on wheat were obtained by (17). In their research, the effects of environment and genotype explained 83.78% and 2.71% of total treatment variance respectively, whereas the interaction explained 10.08% of the total treatment variance. The large environmental sum of squares indicated high variability amongst testing environments within and across years, hence wheat grain yields were significantly affected by the environment. This was also consistent with (11) findings which showed that environment is the dominant source of variation, while G and GE are relatively small in yield trials across locations. According to (18), in normal multi-environment yield trials, E accounts for 80% or higher of the total yield variation, while G and GE each account for about 10%. The magnitude of genotype by environment interaction sum of squares was larger than of genotypes, indicating that there were substantial differences in genotypic responses across environments over the three seasons **(Table 3).** The analysis of genotype by environment interaction pattern is vital for plant breeders in order to design the correct dissemination strategies (wide or specific adaptation) for new genotypes.

Table 3: Combined analysis of variance for grain yield (t/ha) of fourteen wheat genotypes evaluated across seven locations over 3 wheat growing seasons

Source	DF	SS	MS	Explained %
Genotype (G)	13	7.105E+06	5.466E+06	2.03
Environment (E)	6	3.334E+09	5.557E+08	96.2
G×E	78	9.628E+07	1.234E+06	2.75
Coefficient of variation (% CV) =15.6				

The coefficient of variation was 15.6%, indicating good experimental accuracy.

The summary information on the GE main effects and the first principal component scores of the interactions of both genotypes and environments were shown in **Figure 1)**

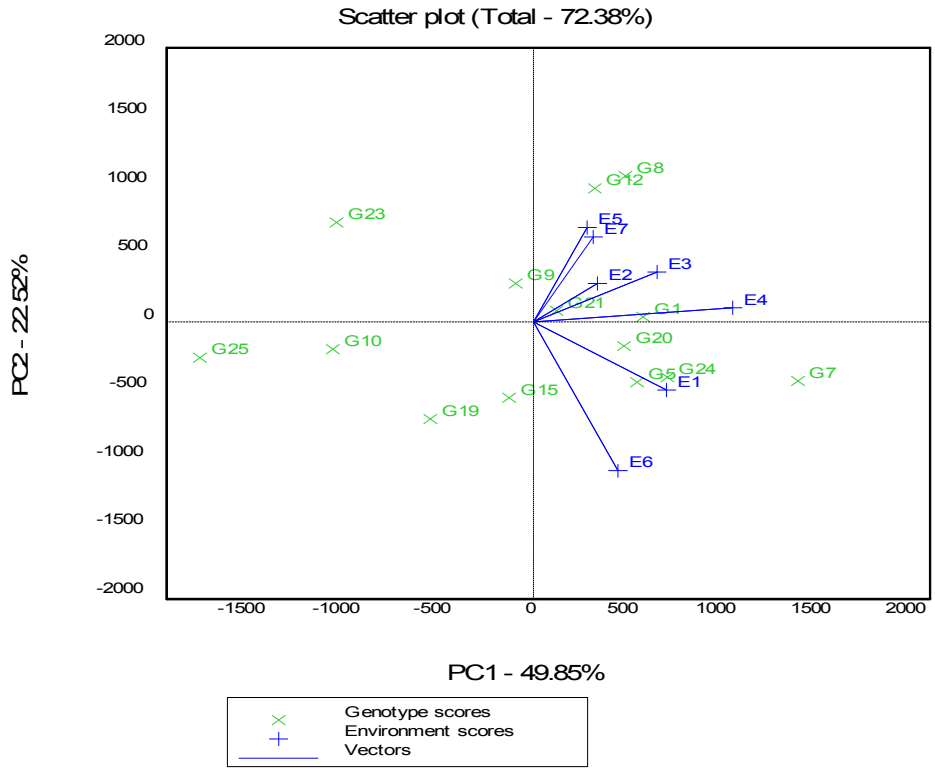

Figure 1: GGE**-bi-plot based on genotype focused scaling for genotypes**

Stability and adaptability analysis

The partitioning of GGE through GGE bi-plot analysis showed that principal coordinate 1 (PC1) and principal coordinate (PC2) significantly explained 49.85% and 22.52% of GGE sum of squares,

respectively, explaining a total of 72.38% variation. This moderate percentage variability of GGE (72.38%) accounted by the bi-plot suggests some strong and complex GE interaction in multi-environment yield trial data. The presence of GEI resulted in differential yield performance among wheat genotypes across testing environments (19). Genotypes or environments with high positive PC1 scores are high yielding while genotypes that had PC1 less than zero scores were identified as lower yielding. PC2 is associated with genotypic stability or instability across environments. Genotypes with low positive or low negative PC2 scores (scores near zero) are more stable than those with large PC2 scores (12). In current study, most of the genotypes locatedon the negative sideof PC1 were check cultivars except for G9**.** This information showed that breeding lines were higher yielding across locations over the three seasons as compared to check cultivars. The elite breeding lines bear potential as candidate cultivars for release. Genotypes G7, G24, G8, G12, G1 and G20 were generally high yielding with G7 being the overall best (largest PC1 score). However, the genotype G7 (Insiza), was characterized as genotype with the highest mean yield and low stability. The results agreed with (5) who stated that higher yielding lines are not always be stable across environments. In contrast, G1 (S01214-3H-ON-2H-ON) was identified as the best genotype in integrating mean yield with highest stability. In contrast, the genotypes G25, G23, G10, G19 and G15 were generally low yielding, with G23 and G19 being part of the most unstable genotypes **(Figure 1).** Such unstable genotypes are not desirable becausetemporal instability has a negative effect on farmers' income and, in the case of staple crops, contributes to food insecurity at national and household level (7, 8). The genotypes G25 and G10 were consistently poor performing hence the high stability**.** Even though G25 was moderately stable, it was the least performing genotype (highest negative PC1 score) with low yields in different environments.

The genotypes formed four groups on the bi-plot (**Figure 1**): 'G25 and G10' generally low yielding, and moderately stable (near zero PC2 scores); 'G23 and G19'generally low yielding and highly unstable (variable) across environments (high positive and negative PC2 scores); 'G7, G24 and G5' generally high yielding, and moderately stable across environments (high positive PC1 scores); 'G20, G1, G21' generally high yielding, and stable genotypes (absolute PC2 scores near zero) across environments (low positive PC1 scores). This indicates that these genotypes may be suitable for growth in a wide range of environments. The genotypes G12 and G8 formed the other group which consisted of generally high yielding and unstable genotypes across environments. The superior, high yielding and stable experimental genotypes (G7, G24, G8, G12, G1 and G20) could be used in crossing with other cultivars for improving grain yield and stability. This is relevant considering that the superior genotypes differed in pedigree; and therefore probably these genotypes could provide further opportunities for genetic gain through recombination of superior alles.

The performance of the genotypes G10, G20, G21, G25 and G1 were high yielding and stable due to their absolute PC2 scores were near zero (**Figure 1**). These five genotypes had little interaction across environments indicating their broad adaptations (20). According to (20), genotypes with PC2 values near zero would have had little interactions across environments and vice versa for environments. All the breeding lines had positive PC1 scores except for G9 which is a CIMMYT bred line. This could be an indication of poor adaptation since it is an exotic line. Local adaptation is also important in variety performance.

Best test environments for wheat

The environment E4 (Mutare) had lower PC2 scores than other environments indicating that it was the most representative site. The environments, E2 (GVTC) and E3 (Panmure) had moderate genotype x environment interaction effects (average PC2 scores). The location E6 (ART farm) exhibited the most unstable yields (high genotype x environment interaction) and would be a good selection site for wheat improvement when targeting a wide range of environments (17).

Genotype X environment interaction

There were inconsistencies in yield rankings of genotypes across environments as shown in **Table 4** and **Figure 1**. Environment PC2 scores had both negative and positive scores. This gives rise to cross over type of GEI indicating that there was inconsistent genotype yield performance across environments. For instance, the following genotypes yielded highest grain yields at different environments; G7 and G24 in E1; G20; G12 in E3; G7 in E4; G8 in E5; G5 in E6; G8 in E7. The presence of cross over GEI shows the existence of different mega environments in which different winning genotypes can be selected (19). Unlike PC2, the environment PC1 scores had only positive environment scores, indicating that there was no difference in rankings of yield performance among genotypes across environments (non cross over GEI). This is shown by some genotypes which attained maximum yields in more than one environment, for instance, G7 (INSIZA) in E1 and E4; G8 (SO2009-8H-0N-3H-ON) in E5 and E7 **(Table 4).** According to (2), it is common for a multi environment yield trial to constitute a mixture of cross over and non cross over types of GEI.

Table 4: **Mean grain yield (t/ha-1) of 14 wheat genotypes evaluated across 7 environments over 3 cropping seasons**

	SITE							
GENOTYPE	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**Mean yield (t ha-1)**
G1	5743	8166	4586	6269	2257	8013	4765	5685
G10	4864	7313	3936	5225	2237	7955	4324	5122
G12	5063	8315	4919	6022	2698	7591	5166	5682
G15	5304	8288	4538	5240	2140	8810	4574	5556
G19	4963	8037	3960	5379	2000	8767	4418	5361
G20	5056	8781	4642	5801	2336	9008	5094	5817
G21	5787	7957	4831	5218	2436	8200	5164	5656
G23	4177	8074	4056	5211	2623	7733	4902	5254
G24	5861	8363	4616	6000	2592	8695	4498	5804
G25	4779	8147	3653	4377	1696	7755	4281	4955
G5	5480	7906	4514	5867	2514	9100	5183	5795
G7	5888	8385	4818	6957	2232	8705	4579	5938
G8	5122	8735	4819	5881	3035	7846	5411	5835
G9	5026	8322	4608	5587	2746	8108	4469	5552
Mean	5222	8199	4464	5645	2396	8306	4773	

E1: Harare, E2: GVTC, E3: Panmure, E4: Mutare, E5: Save Valley, E6: ARTfarm, E7: Chisumbanje

G1: SO1214-3H-ON-2H-ON, G10: KANA, G12: S02147-7H-ON-3H-0N, G15: STALLION, G19: KAME, G20: S02006-5H-ON-1H-ON, G21: SMART, G23: PAN 3492, G24: S02147-2H-0N-2H-ON

G25: SHIELD, G5: Dande, G7: INSIZA, G8: SO2009-8H-0N-3H-ON, G9: F02048

Which-won-where' patterns

The polygon view of a bi-plot is the best way to visualize the interaction patterns between genotypes and environments (11). Visualization of the "which won where" pattern of MET data is necessary for studying the possible existence of different mega environments in the target environment (6). A five pentagon polygon was formed from vertex or corner genotype, G25, G23, G18, G7 and G8**,** werefurthest from the bi-plot origin (0.0) (**Figure** 2).

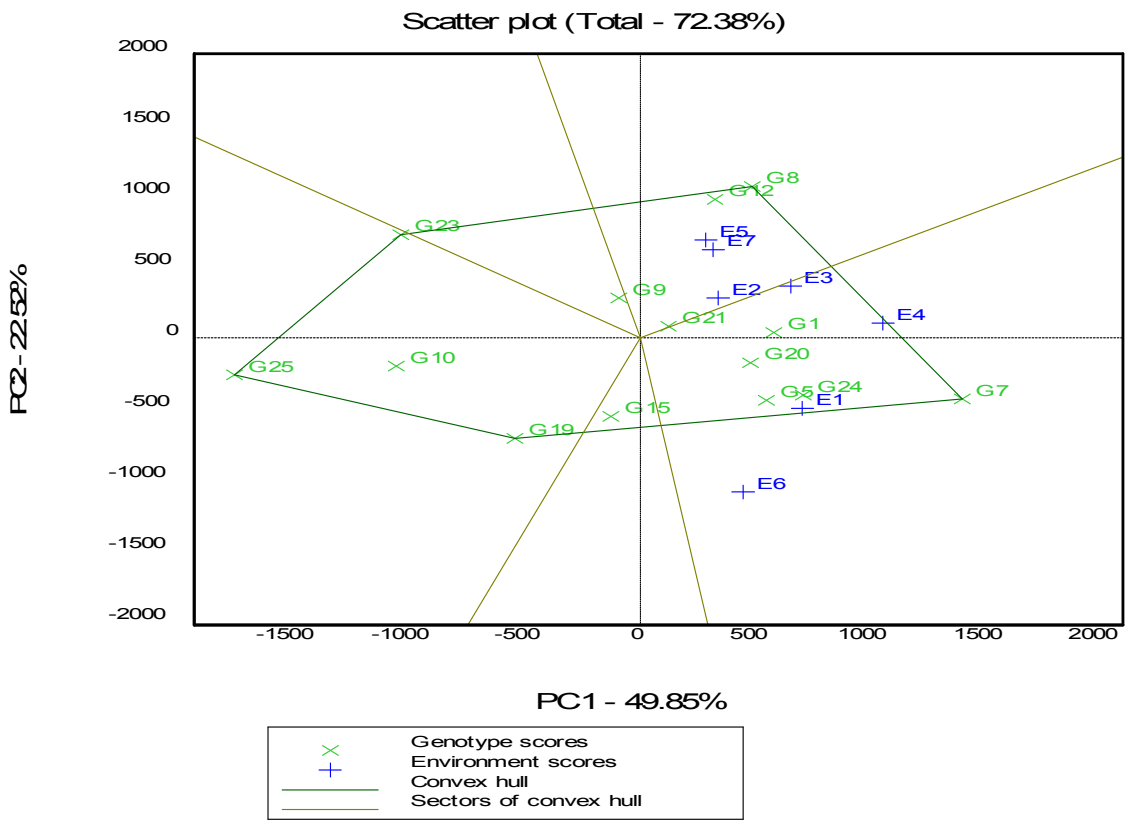

Figure 2: Polygon view of genotype environment interaction for fourteen wheat genotypes over seven test environments.

These vertex genotypes were the best or the poorest genotypes in some or all of the environments in that sector because they were furthest from the origin of the bi-plot. Thus vertex genotype in each sector is the best genotype at environments whose markers fall into the respective sector. The convex hull is drawn in such a way that all genotypes are contained within it. When the bi-plot was divided into several sectors by the perpendicular lines, five sectors were obtained (**Figure 2).** Within these sectors are environments. Environments within the same sector share the same winning genotype, and environments in different sectors have different winning genotypes. The cultivar G7 (Insiza) which is sector 1 was the best (winner) genotype for environments E1 (Harare),

E3 (Panmure) and E4 (Mutare). This is because these three environments fell in the sector in which Insiza was the vertex genotype. Also within this sector, the genotypes G20 and G24 were second and third winners respectively after G7. The environments E2 (GVTC), E5 (Save Valley) and E7 (Chisumbanje) fell in the sector in which G8 (SO2009-8H-0N-3H-ON) was the vertex genotype, meaning that G8 (sector 2) was the best yielder for these three environments (**Figure 2**). The genotypes G12 and G21 were second and third winners respectively in this sector. Environment E3 (Panmure) had two best genotypes, G8 and G7 as shown in **Figure 2.** Thus out of the five sectors, only two (G8 and G7) had environments withinthem suggesting that only two mega-environments can be formed if the patterns identified are repeatable as shown in **Figures 2 and 3**.

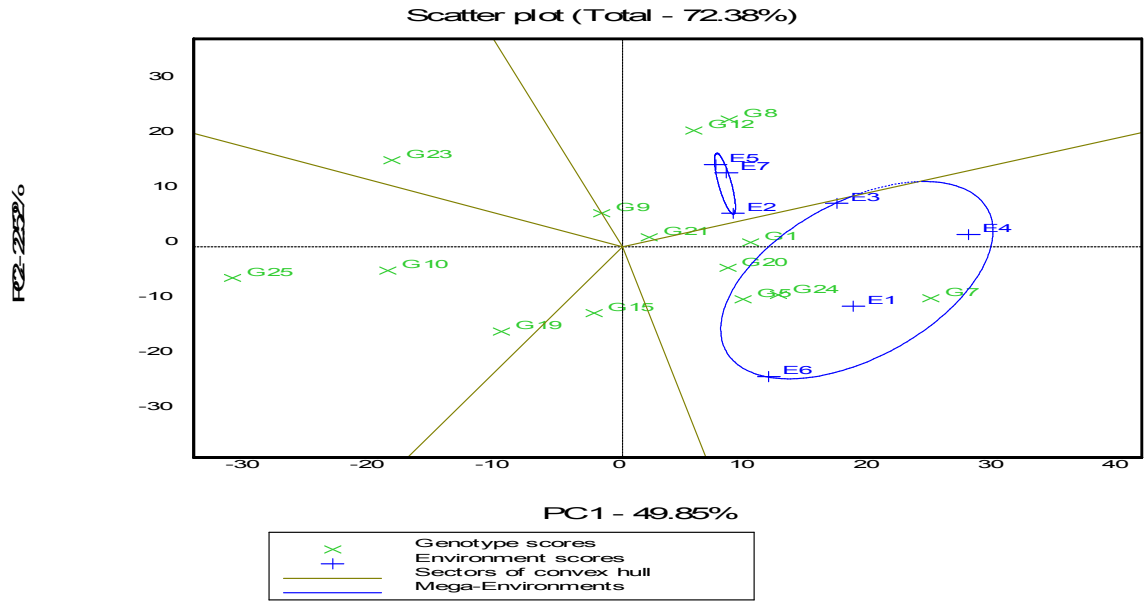

Figure 3: Bi-plot presentation data for mega-environments

The sector 1 formed mega environment 1 and sector two formed mega environment 2 **(Figure 3)**. The G and GE will be effectively exploited by selecting superior cultivars for each mega-environment. The vertex genotypes G25, G18 and G23 were not the top yielding genotypes in any environment **(Figure 2)**. Subsequently, the genotypes G25, G10, G19, G23 and G15 (all with negative PC1 scores) were not included in any one of the five sectors with testing environments suggesting that they were the least performing in most of the testing sites**.**

Environmental Correlations

To examine relationships among environments, environmental vectors are drawn to connect the test environments to the bi-plot. The correlation between two environments can be approximated by the cosine of the angle between the vectors of two environments. **Table 5** shows the correlation

coefficients among 7 test environments. The succinct summary of the correlation among the test environments is shown by the vector view of the GGE-bi-plot in **Figure 1**. Two environments are positively or negatively correlated if the angles between their vectors are less than 90° or more than 90° (5) respectively. Thus, the environments E5 and E7 were positively correlated with E2. There was also a positive correlation between E4 and E1. The correlation between E3 and E6 was close to zero (**Table 5**) and this is also shown in **Figure 1** where the angle between them was close to 90°. This indicates weak associations between the two environments. However, some inconsistences were observed and this was expected because the GGE bi-plot did not explain 100% GGE variation (21). For instance, **Figure 1** showed the existence of very close correlation between E2 and E3 but the actual correlation was negative **(Table 5).** Also figure 1 showed that there were positive correlation between E4 and E3 but the actual correlation was negative as indicated in **Table 5.**

Table 5: Correlation co-efficient among seven test environments across three seasons

	E1	E2	E3	E4	E5	E6	E7
E1	1.00						
E2	0.6199	1.00					
E3	-00792	-0.0436	1.00				
E4	0.5358	0.5029	-0.0739	1.00			
E5	0.6865	0.4972	0.0327	0.3296	1.00		
E6	0.4241	0.2712	0.1281	0.2593	0.3286	1.00	
E7	0.7006	0.5674	0.0206	0.4318	0.7361	0.3090	1.00

According to (19), the presence of close association between testing environments reveals that same information about the genotype could be obtained from fewer test environments and hence there could be better potential to reduce testing cost under limited resources.

Discriminating power and representativeness of locations

Among the 7 testing environments **(Figure 1),** E4 (Sisal, Mutare) with longest environmental vector and largest PC1 score was the most discriminating, while E2 (GVTC) was the least discriminating environment. If an environment is consistently none-discriminating, it may be discarded as a testing site because it provides little information (non-informative) about the cultivars. An average environmental axis (AEA) is the line that passes through the average

environment and bi-plot origin. An average environment is represented by a small circle. Among all the test environments, E4 (Mutare) was the most representative (smallest angle with AEA) and E6 (ART farm) was the least representative (largest angle from the AEA) environment **(Figure 4).** According to (12), a test environment that has smaller angle with AEA is more representative of other test environments. The environment E4 (Mutare) was the ideal (center of concentric circles) test environment because it was the most discriminating and best representative environment among all the environments **(Figure 4).** Thus, E4 was a good test location for selecting widely adapted genotypes and it was the best environment for genetic differentiation of experimental genotypes.

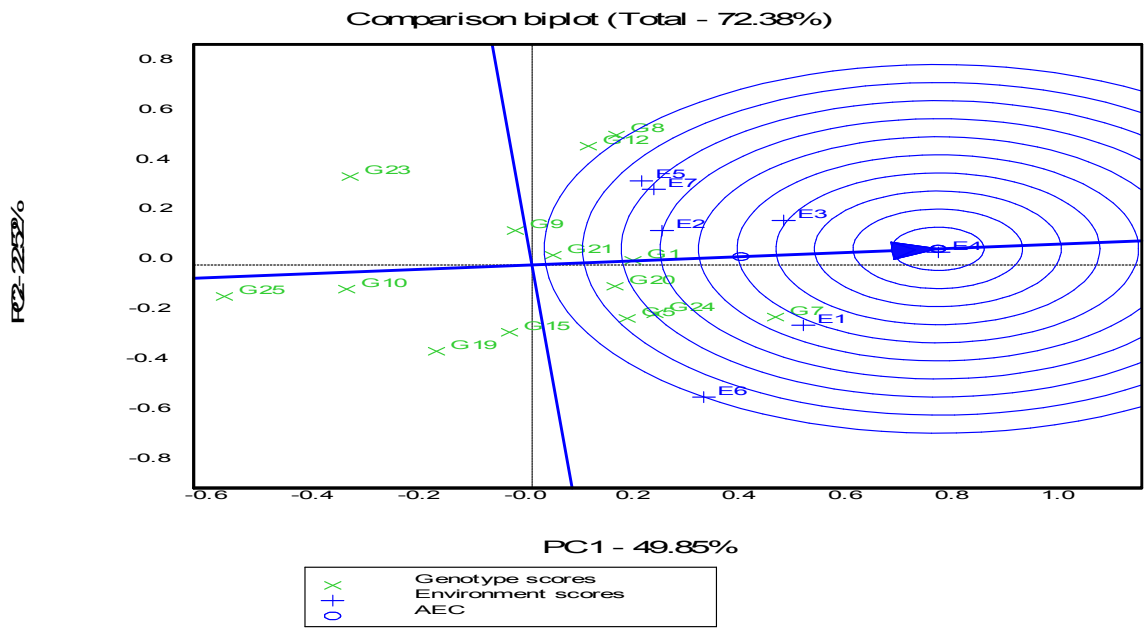

Figure 4: The discriminability and representativeness view of the GGE-biplot of the test environments.

An ideal genotype should have the highest mean performance and be absolutely stable (11).

CONCLUSIONS

GGE bi-plots are useful tools that can aid breeders and agronomist in identifying stable wheat genotypes with high yield performance. The results indicated that yield performance of genotypes was highly influenced by environment effect followed by the genotype environment interaction and genotype with the least effects. This showed that the GE interaction pattern is complex. The best and least performing genotypes across the three seasons were G7 (Insiza) and G25 (Shield) respectively. The most stable genotypes were G1 (SO1214-3H-ON-2H-ON), G20 (S02006-5H-ON-1H-ON) and G21 (Smart) and the most unstable genotypes were G8 (S02009-8H-0N-3H-ON) and G12 (S02147-7H-ON-3H-0N). The breeding lines G1 (S01214-3H-ON-2H-ON), G20 (S02006-5H-

ON-1H-ON) and G24 (S02147-2H-0N-2H-ON) performed relatively well across the three seasons and will be recommended for further testing in farmers fields. The environment E4 (Sisal, Mutare) was the most discriminating and best representative location and E2 (GVTC) was the least discriminating site. The highest positive correlation was observed between environment E5 (Save Valley) and E7 (Chisumbanje). This means one test location can be chosen between them to reduce testing costs since they are likely to give same information about the genotypes. The genotype G7 (Insiza), was characterized as genotype with the highest mean yield and low stability. In contrast, G1 (S01214-3H-ON-2H-ON) was identified as the best genotype in integrating mean yield with highest stability performance. Most of the breeding lines were generally higher yielding compared to check cultivars as all the genotype that were located on the negative side of PC1 were check cultivars except for G9 (F02048). The polygon view of genotype environment interaction showed that only two mega-environments can be formed if the patterns identified can be repeated.

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Efficacy Of Botanical Extracts From Garlic (*Allium Sativum*L.) And Neem (*AzadirachtaIndica* A. Juss) On Controlling Potato Soft Rot Pathogens

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Two botanicals extracts, neem (*Azadirachtaindica* A. Juss.) leaves and garlic (*Allium sativum*L.) cloves were evaluated for controlling potato soft rot caused by *Pectobacteriumcarotovorum* subspecies*carotovorum*(*Pcc*), *Pectobacteriumatrosepticum* (*Pa*) and *Dickeyadadantii* (*Dd*). Two concentrations [(10 and 25% (w/v)] of aqueous extracts of garlic and neem plants were used in dip and spray applications. Five 10 mm filter paper discs (Whatman's No. 1) pre-soaked in1 x 10^6 colony forming units/mlbacterial cellsuspensions were placed on each potato tuber half and incubated for 48 h at 25°C. The experiment was a Completely Randomised Design, 3x2x2+1 factorial. The botanicals significantly inhibited the growth of *Pa* and *Dd* but were ineffective against *Pcc* (P=0,006). Concentration, method of application and their interactions were not significant in inhibiting the bacteria. Neem and garlic extracts can be used to control *Pa* and *Dd* infections.

Key words: Neem, Garlic, *Pectobacterium*spp., *Dickeyadadantii*

INTRODUCTION

Bacterial soft rot of potato has become a very important disease world-wide due to the losses it causes during the various stages of crop development and in storage (30,5). *Pectobacterium* and *Dickeya* species are known to cause soft rot, blackleg and wilting diseases that cause huge amounts of economic losses (3). Sub-species described under *Pectobacterium*: *atroseptica*, *carotovora*, *betavasculorum*, and *wasabie*(12,3) and sub-species under *Dickeya*: *dadantii*, *zea* and *dianthicola*(33) are known to cause serious disease on potato. Potato blackleg is caused by *P.atroseptica* (*Pa*) in cooler climates and *P.carotovora* subsp. *carotovora* (*Pcc*) and *D. dadantii* (*Dd*) cause similar symptoms in higher temperatures (12). In Zimbabwe, losses due to *D. dadantii* have been reported to be around 20-60% (20). Under bad handling conditions, losses can reach to about 100% (9,18)

Over the years, inappropriate use of agrochemicals, especially fungicides, has resulted in pathogen resistance and undesirable side effects due to their carcinogenic properties (1). The promotion of environmentally sustainable agriculture and organic agriculture has led to alternatives such as the use of natural plant products (31). The use of plant products is gaining popularity because they have been found to be non-toxic, more systemic with little mammalian toxicity (4).

The antimicrobial substance, allicin, which is produced in garlic is active against a wide range of pathogens both *invitro* and *invivo*(28). Garlic has been shown to be effective against *Phytophthorainfestans*(10,28) on tomato seedlings. Mycelia growth of *Fusariumsolani* (8) and *Rhizoctoniasolani* (7) was also inhibited by garlic extracts (7). Flavonoids and saponins of red garlic exhibited anti-bacterial properties against *Bacillussubtilis*(16).

Neem products have been used mainly in insect pest management because of their pesticidal and anti-feedant activities (5,31). The most active substance in neem preparations is azadirachtin(31) and this is active against a wide range of pests (15). However, neem has been found to have fungicidal (4,13) and bactericidal (17,31) properties.

It is important that more botanicals are explored and evaluated for their efficacy against plant pathogens. With scientific improvement, botanicals might be a low cost solution in plant protection, and this will become a real social value to the subsistence farmer.

This work seeks to evaluate the efficacy of extracts from two plants that have been reported to have antimicrobial properties, garlic (*Alliumsativum*) (30) and neem (*Azadirachtaindica*) (4,1) on controlling potato soft rot caused by three soft rot causing bacteria, *Pcc*, *Pa* and *Dd*.

METHODOLOGY

Preparationofplantextracts

The aqueous plant extracts and their concentrations were prepared according a method described by (5), with minor modifications. Neem leaves were harvested from a tree at Chiredzi Research station and garlic cloves were bought from a local supermarket. The aqueous plant extracts of neemleaves and garlic cloves were prepared separately in two concentrations: 25% and 10% (w/v) by blending 1 kg of garlic cloves/neem in four litres and 1 kg of garlic cloves/neem leaves in ten litres of water respectively. The mixture suspension was filtered through a 1 mm sieve. The plant extracts were then stored for later use in a refrigerator at 4˚C for approximately one month.

Inoculum preparation

The pure culture strains of *Pcc* (LMG 2404□, Belgian Coordinated Collection of Microorganisms), *Pa* (LMG 2386□, Belgian Coordinated Collection of Microorganisms) and *Dd* (3937□, Scottish Crop Research Institute), were obtained from the Plant Pathology Laboratory, Crop Science Department at the University of Zimbabwe. The isolates were re-initiated in nutrient broth (NB) and re-streaked on Nutrient Agar (NA) solid media for purity. The cultures were transferred into Luria Bertani (LB) liquid media and bacterial suspensions were adjusted to a concentration of 1 X 10^6 cells/ml using a spectrophotometer at OD_{600}.

Potato tuber maceration test

The variety Pimpernel was used. Potato tubers of medium sized were washed using tap water, surface sterilized in 10.0% sodium hypochlorite solution for 5 minutes and then rinsed in sterile water. Tubers were allowed to air dry and cut longitudinally into halves. Botanical treatments were applied on the cut surfaces using dip and spray treatment application of neem and garlic extracts at two concentrations [25% (w/v) and 10% (w/v)]. Treatment applications were done approximately for 5 seconds for each tuber half. Tuber halves treated with sterilized distilled water were used as a negative control.

Five filter papers (Whatman's No. 1) discs, 10 mm in diameter, were soaked in individual bacterial suspensions of *Pcc*, *Pa* and *Dd*, all with a concentration 1 X 10^6 cells/ml. Soon after dipping or spraying application of botanical extracts, inoculated filter paper discs were placed on each tuber half and then incubated at 25˚C for 48 hours. The inoculated tubers were placed in transparent plastic bags with a moist absorbent paper at the bottom to maintain humid conditions necessary for disease development. After 48 h, the filter paper discs were removed and the rotting zone diameter was measured in mm using a ruler.

Experimental design and statistical analysis: The experiment was laid out in a Completely Randomised Design with a 3x2x2x2+1 factorial treatment structure with a control. Each treatment was replicated three times. Average rotting zone diameters for each treatment were used in analysis. Data were analysed with Genstat Version 13 as a 3x2x2x2+1 factorial using the control as a dummy variable. When F test was significant ($P<0.05$), the means of different treatments were compared to the control using LSD at 5% level. To calculate inhibition percentage, the following formula was used;

% inhibition = [(mean diameter of control – mean diameter of test / (mean diameter of control)] x 100%

RESULTS

There were highly significant effects in bacterial growth for the control, bacteria and botanicals due to the application of botanical extracts (P<0.001, Table 1). In addition, the interactions bacteria x botanical x concentration (P =0.003) and bacteria x botanical x methods (P =0.008) were highly significant. The effects of concentration, method of application and their interactions were not significant in inhibiting the bacteria.

Table 1: Analysis of variance table showing the effect of three bacterial subspecies, botanical concentration and application method on soft rot.

Source	DF	SS	MS	F	P
Control	1	0.6974	0.6974	7.52	0.008
Bacteria	2	31.7255	15.862	170.94	0.001
Botanical	1	0.7792	0.7792	8.40	0.006
Concentration	1	0.0397	0.0397	0.43	0.516
Method	1	0.183	0.183	1.97	0.166
bacteria*botanical	2	0.2338	0.1169	1.26	0.293
bacteria*concentration	2	0.2186	0.1093	1.18	0.316
bacteria*Method	2	0.0915	0.0458	0.49	0.613
botanical*concentration	1	0.078	0.078	0.84	0.364
botanical*Method	1	0.4156	0.4156	4.48	0.303
concentration*Method	1	0.1005	0.1005	1.08	0.303
bacteria*botanical*conc	2	1.234	0.617	6.65	0.003
bacteria*botanical*Meth	2	0.9978	0.4989	5.38	0.008
bacteria*concentration*Meth	2	0.563	0.2815	3.03	0.057
botanical*concentration*Meth	1	0.0017	0.0017	0.02	0.893
bact*bot*conc*Meth	2	0.3409	0.1705	1.84	0.170
Error	50	4.6421	0.0928		
Total	74	42.3422			

The comparison of the different treatment means with the control is presented in Figures 1 and 2. Garlic and neem extracts were not effective against *Pcc* when compared with the control in all treatments.

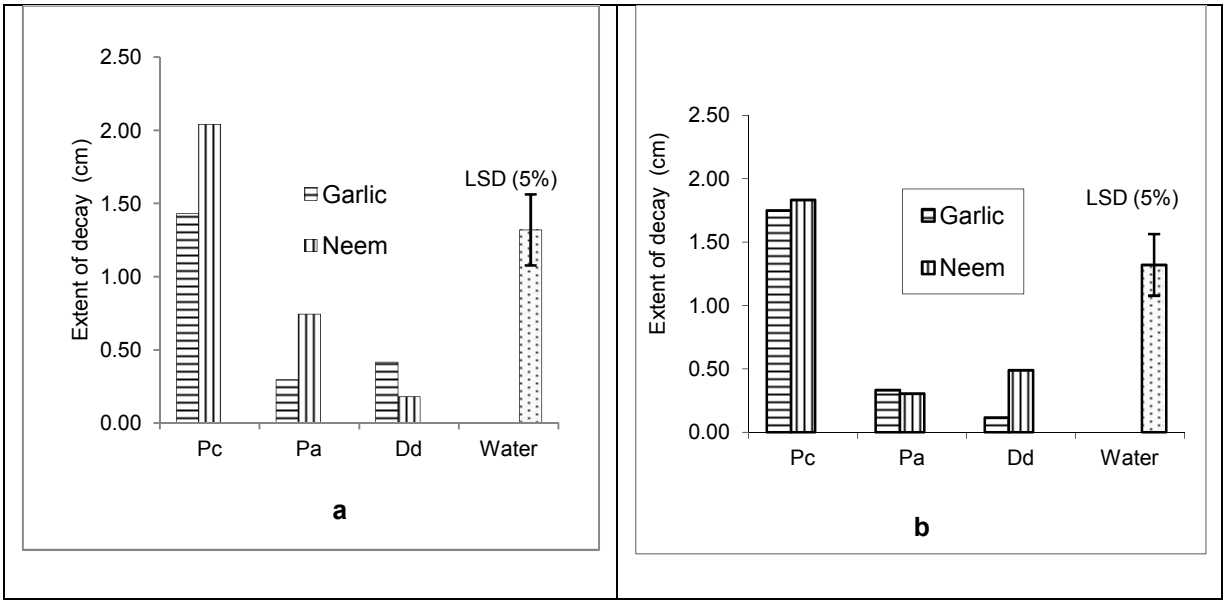

Figure 1: Efficacy of garlic (clove) and neem (leaf) extracts at 25% (a) and 10% (b) concentration in (dip/spray) treatment application against *Pcc*, *Pa* and *Dd* pathogens. Sterilized distilled water used as a control treatment.

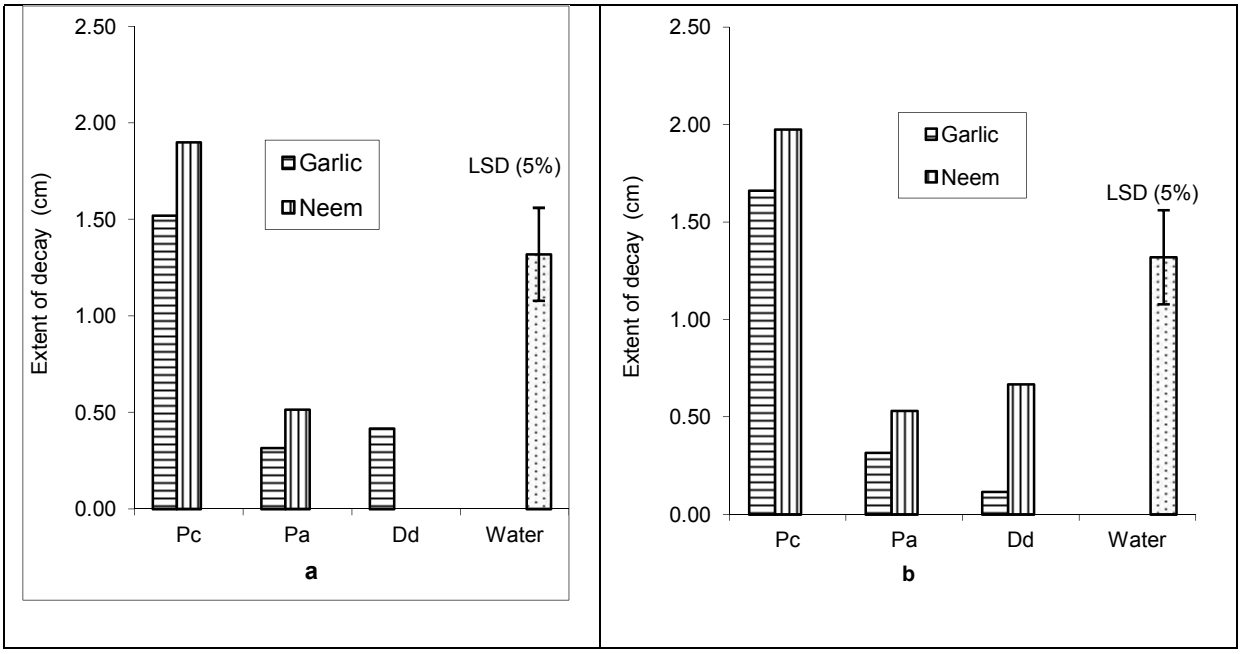

Figure 2: Efficacy of garlic (clove) and neem (leaf) extracts in dip (a) and spray (b) treatment application against *Pcc*, *Pa* and *Dd* pathogens. Sterilized distilled water used as a control treatment.

DISCUSSION

The experiment results showed that the use of botanicals led to a reduction in the severity of soft rot on two bacterial species, *Pa* and *Dd*. When compared to the negative control, inhibition of bacterial growth by garlic was 45.2% while neem inhibited growth by 29.4%. Similar work that has been done on botanicals has shown that plant extracts from garlic and neem have anti-microbial properties against a wide range of plant pathogens (2), though garlic showed to be the most effective against *Rhizoctoniasolani* (1), when tested with other plants such as half-bar, carnations, craway and neem. Neem contains a compound known as mahmoodin, which has significant antibacterial activity against gram-positive and gram-negative micro-organisms (17). The anti-bacterial nature of garlic is widely attributed to allicin, which has inhibitory effects to both gram-positive and gram-negative bacteria (14). Both botanicals are effective against bacteria such as *Staphylococcusaureus* (14,17).

The results also showed that the three bacterial sub-species behaved differently in response to the botanicals. *Pcc* was the most aggressive and did not respond to the botanical treatments, followed by *Pa*, whose growth was inhibited by 68.3% following botanical treatments. The botanicals proved most effective against *Dd* by inhibiting its growth by 77.3%.

Variation in pathogenicity of different sub-species of soft rot bacteria is related to the different amounts of pectic enzymes (6). Pectolytic bacteria cause rotting by producing enzymes such as pectinases, cellulases and proteases which cause tissue maceration (27). Pectinases are the main enzymes involved in tissue maceration and they are grouped into pectatelyase (PL), pectin lyase (PnL), polygalacturonase (PGN) and pectin methyl esterase (PME). They exist as isoenzymes encoded by independent genes (25). The PL enzymes are the main pectinases involved in pathogenesis, and their number varies between species, sub-species and strains (32). According to (26), there are five major PL enzymes grouped into two families, PL A, D, E and PL B, C in *Dd,* four major PL enzymes (PL A, B, C and D) in *Pcc* and three major PL enzymes (PL A, B and C) in *Pa*. Although production of these pectinases is important for pathogenicity, not all isoenzymes are required in all situations. In *Dd*, for example, PL A, D and E family plays a larger role in pathogenicity than the PL B and C family. Another difference is in the role of PME. In *Dd*, PME has been shown to play a major role in pathogenesis while PG and PnL appear to contribute more to the pathogenicity of *Pcc*(26,32).

Secretion of exoenzymes is also regulated differently amongst different bacterial species. There are three secretion systems (Type I, II and III). The Type I system secretes protease from the cytoplasm into the extracellular space and has a minor role in pathogenicity. The Type II system is essential in

pathogenicity and secretes pectinases and cellulases. The Type III system translocates effector proteins into host plant cells to assist in bacterial virulence (11,32).

Their pathogenicity is also temperature dependent (26). The pectin enzyme, endopolygalacturonictranseliminase (PGTE) production by *Pa* is higher at lower temperatures (< 15˚C) but undetectable at 30˚C. In contrast, production of the enzyme in *Pcc* is equally high at 15˚C and 30˚C. Strains of *Pcc* and *Dd* that would have lost the ability to produce large quantities of PGTE during the course of the experiment lose virulence (24). Since all the bacteria were exposed to the same temperature of 25˚C, this might have favoured pectic enzyme production in *Pcc* better than in *Pa* and *Dd*. Resultantly, *Pcc* gave the highest tissue maceration followed by *Pa* and *Dd*.

The most commonly used solvents for the extraction of plant extracts are water, ethanol and methanol (19). Successful separation of botanical compounds is largely dependent on the type of solvent used. Alcoholic extracts have been shown to provide more antimicrobial activity compared to water (22). Active compounds from aqueous extractions lack solubility or are present in insufficient amounts (24). Because of this limitation in aqueous extracts, there is a probability that the botanicals in this experiment were therefore only effective against the less virulent sub-species, *Pa* and *Dd.* Although aqueous extracts of neem and garlic have previously been shown to exhibit moderate control even against *Pcc*(29), in this study, the botanicals were not effective against *Pcc*. This suggests that the aqueous extracts of the botanicals did not provide sufficient active compounds to suppress the pathogen.

Dipping or spraying as a method of botanical application had no significant difference on the extent of rotting. In a similar study by (5), in which unwounded tubers were submerged in or sprayed with neem extracts for longer periods, there was a reduction in the incidence and severity of soft rot regardless of the application method. If the two methods tend to give similar results, it is therefore better to use the spraying method because it is easier and more practical than dipping, and might result in less rotting because it uses less water. Dipping, on the contrary, leaves a film of water on the potato surface which causes anaerobiosis. Anaerobiosis is important for the initiation of tuber decay because it impairs oxygen dependent host resistance systems, leading to rotting (25). Therefore, it is possible that dipping can confound results due to its effect on enhancing rotting.

CONCLUSION

In this study, garlic and neem provided control on potato soft rot caused by *Pa* and *Dd* but were not effective against the *Pcc*. The results suggest that garlic and neem have anti-microbial compounds that can be used to control *Pa* and *Dd* infections.

RECOMMENDATION

Further work needs to be done using alcoholic extracts such as methanol and ethanol.

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Title: Investigating the potential use of water hyacinth (*Eichhorniacrassipes*) for biogas and organic fertiliser production

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Abstract

Different fermentation conditions were investigated for their effects on the biogas yield from water hyacinth (*Eichhorniacrassipes*). The study was conducted over a period of 45 days using batch fed anaerobic digesters. A water hyacinth to water ratio of 1:4 exhibited maximal biogas production and the highest amount of biogas with an average methane content of 58% was generated in the temperature range 31°C to 40°C. Co-digestion of water hyacinth with cow dung at a ratio of 3:1 respectively was shown to improve the yield of biogas and methane content (72% of the total biogas produced). The obtained digestion slurry had higher nitrogen (1.91%), phosphorus (2.22%) and potassium levels (2.84%) compared to organic fertilisers such as dung manure commonly used by small scale farmers in Zimbabwe. There is a need to raise awareness on the potential application of water hyacinths as cheap sources of high quality biogas and organic fertiliser.

Key words: water hyacinth, biogas, organic fertiliser

INTRODUCTION

Water hyacinths (*Eichhorniacrassipes)* is an invasive aquatic plant that is native to the Amazon basin and its presence in Zimbabwe was first recorded in the Mukuvisi and Manyame (formerly Hunyani) rivers in 1937 (1). The plant due to its high growth rate (and lack of a natural predator in Zimbabwe) subsequently became a serious pest in the major water bodies of Zimbabwe and by the late 1980s it had infested Lake Kariba, Lake Mutirikwi and Lake Chivero(1). Chemical control, physical/mechanical control and biological control methods have been employed in Zimbabwe to control the weed with varying levels of success. Biological control of the water hyacinth has been effective in Zimbabwe as shown by the reduction in weed coverage in Lake Chivero from an estimated 35% in the late 1980s to 3% by the late 1990s after the introduction of the weevil

*Neochetinaeichhorniae*as a biocontrol agent (2). The economic challenges and resultant breakdown in infrastructure faced by Zimbabwe in the lost decade (2000-2010) negatively affected the progress that had been made in controlling water hyacinth (and other alien plant species) and according to the Environmental Management Agency (EMA), water hyacinth is now a common feature characteristic of water bodies in Mashonaland(3). It is estimated that the Government of Zimbabwe needs over US$50 million annually to control water hyacinth and other alien plant species (3). Experts in the area of water hyacinth research believe that it is difficult to eradicate the water hyacinth as the conditions that allow it to proliferate are difficult to control (4).

Biomass is biological material obtained from living or recently living plant matter that can be processed into energy (electricity, fuel and heat) and it accounts for 61% of the energy used in Zimbabwe (5)(6). Fuel wood is the most important domestic fuel in the country as it is a major source of energy for over 80% of the rural and peri urban population (7). The excessive dependency on fuel wood has resulted in environmental degradation and there is a need to find alternative sources of energy which are renewable and friendly to the environment (6).

Eichhorniacrassipes is an excellent source of biomass due to its high biomass growth rate (up to 17 tonnes per hectare per day) (8)(9) and in countries such as India, Nepal Bangladesh; it has shown potential as a source of renewable energy in the form of biogas (10). Biogas is a combustible mixture of methane (50 -70%) and carbon dioxide with traces of hydrogen sulphide and water. Biogas is formed naturally from the anaerobic bacterial decomposition of organic matter and in the process gives organic fertiliser as a secondary by-product (11)(12). The anaerobic decomposition of organic matter occurs in four phases (hydrolysis; acidogenesis; acetogenesis and methanogenesis).

The biomass conversion efficiency of water hyacinth to biogas has been shown to be around 38% (13) (14). Numerous studies to improve the biomass conversion efficiency and biogas yield from water hyacinth have been conducted worldwide (15). The high suitability for the use of water hyacinth as an organic fertilizer may be attributed to its low and narrow margin carbon: nitrogen ratio (C:N) of 1:25 and low lignin content of only 9% compared to other plant materials (such as wheat straw) commonly used for mulching and preparing composts (16). There are commercially available organic fertilisers (such as Ecogreen manufactured by Soamso Ltd, Equador) that are derived from the aerobic decomposition of water hyacinth (17). There are several nutrient content values cited in literature for liquid organic fertilisers derived from water hyacinth. The cited nitrogen levels range from 1.9 – 4%, the phosphorus levels range from 1 – 2.9%, and the potassium levels range from 2.9 – 3.3% (17) (18) (19). However, in Zimbabwe, limited research has been conducted on the potential application of water hyacinth for biogas and concurrent organic fertiliser production.

The goal of this study was to investigate the potential use of water hyacinth for biogas and concurrent organic fertiliser production in Zimbabwe.

OBJECTIVES

The objectives of the study were to determine the water hyacinth optimum biogas production conditions (for selected parameters) and evaluate the composition of the digestion slurry for use as an organic fertiliser.

METHODOLOGY

Sample Collection and Preparation

Water hyacinth used for the study was obtained from the sewage stabilisation ponds (at the Scientific and Industrial Research and Development Centre in Hatcliffe, Harare Zimbabwe). The cow dung was collected from the SIRDC cattle pen. The water hyacinth was hand-pulled from the source and put into polyethylene bags which were tied up to avoid wilting of the plants. The plants were rinsed under running water upon arrival in the laboratory to remove external contaminants and were then chopped into small pieces.

Biomethanation unit

The biomethanation unit consisted of 5 litre polyethylene containers (anaerobic digesters) which were sealed by a two way rubber stopper and connected by a gas pipe through one of the stoppers to a measuring cylinder. In order to prevent the dissolution of biogas in the water, an acified brine solution was prepared by adding sodium chloride to water until a supersaturated solution was formed. Little drops of sulphuric acid were added to acidify the brine solution. A series of batch-fed reactors were placed together for studying the biogas production under varying conditions. The biogas evolved was measured using the water displacement method (20).

Sample analysis

pH analysis: pH was measured using a pH meter (Knick 766 Calimatic) which was calibrated and operated according to the manufacturers' specifications.

Temperature analysis: temperature was measured using a bulb thermometer (0-100°C).

Biogas analysis: the biogas gas composition analysis was done using a Geotech portable biogas analyser.

Digestion slurry analysis: Nitrogen (N_2) composition was determined using the Kjeldahl method; Potassium (K) composition was determined using atomic absorption spectroscopy (AAS – GBC); Phosphorus (P) was determined using the UV/VIS spectrophotometer (Shimadzu)

The negative control for all the parameters tested was a digester that only contained water and no substrate.

Effect of water hyacinth dilution (ratio of water hyacinth to water) on biomethanation

The effect of dilution on biomethanation was tested at water hyacinth: water ratios of 1:1, 1:3, 1:4, 1:5 and 1:6. The digesters with the different ratios were set up in duplicate and the incubation period was 40 days. The temperature and the pH in the digesters were measured after every 3 days and the volume of biogas produced was measured after every 24-48hours. This study was conducted at room temperature.

Effect of temperature on biomethanation

This was evaluated in the temperature range $10^{O}C$ to $55^{O}C$ at a water hyacinth: water ratio of 1:4. The digesters at the different temperatures ($5^{O}C$ intervals) were set up in duplicate and the incubation period was 40 days. The biogas composition was analysed after every 5 days.

Effect of co-digestion of with cow dung on biomethanation

The effect of co-digestion with cow dung was investigated at water hyacinth: cow dung ratios of 1:1, 1:3, and 3:1 respectively. The digesters were set up in duplicate and incubated in the temperature range $31\text{-}41^{O}C$ for 45 days. The temperature and the pH in the digesters were measured after every 3 days and the volume of biogas produced was measured after every 24-48 hours. The biogas composition was analysed after every 5 days.

Nutrient analysis of the digestion slurry

Samples of 40 days digestion slurry were collected and filtered and centrifuged at 10,000 rpm for 15 minutes. The resulting supernatant was then taken for nutrient analysis.

Data analysis

The data was analysed using the Data Analysis ToolPak (Microsoft Corporation, 2010). Statistical analysis of variance was carried out using one-way ANOVA with the alpha value of 0.05.

RESULTS

Effect of water hyacinth dilution

The dilution ratio of 1:4 produced the highest amount of gas over the 40 day incubation period. Water hyacinth dilution had no significant effect on temperature and pH within the digesters.

Table 1: Mean amount of biogas produced per dilution ratio in 40 days

Dilution Ratio	Average biogas yield (ml/100g)*
1:1	113 ± 0.5
1:3	827± 7
1:4	1253± 2
1:5	833± 6
1:6	804± 3.5

The total amount of biogas produced per 100g of substrate was significantly different between the different dilution ratios ($p<0.05$) hence diluting water hyacinth has a significant effect on biogas production.

Effect of temperature on biomethanation

Incubation temperature had an effect on both the biogas production and methane content of the generated biogas. The highest volume of biogas was produced in the incubation temperature range of 36-40°C. The highest methane content by percentage of the biogas was recorded in the temperature range 10-15°C (68%). However, the highest amount of methane by volume was produced in the incubation temperature range of 31-40°C. Increasing the incubation temperatures had an effect of decreasing the methane content of the generated biogas.

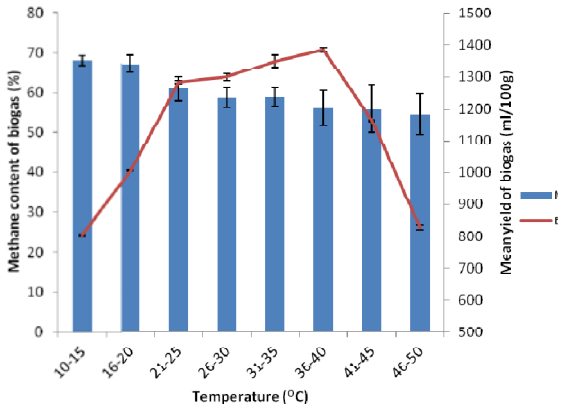

Figure 1: Effects of temperature on biomethanation

Low (10-15°C) and high (46 - 55°C) incubation temperatures resulted in the generation of the least amount of biogas.

Effect of co-digestion of with cow dung on biomethanation

The mixing ratio of cow dung to water hyacinth had an effect on the total biogas production ($p<0.05$).

Table 2: Gas production and methane content at different water hyacinth to cow dung ratios

Substrate mixing ratios (water hyacinth: cow dung)	Gas production (ml/100g)	Methane content (%)
1:1	1583±7	65
1:3	1377±1	68
3:1	1442±5	72

The highest methane content was observed in the water hyacinth: cow dung ratio of 3:1 and co-digestion had no significant effect on the digester temperatures. All the digesters operated at a pH range between 6.3 and 6.8.

Nutrient analysis of the digestion slurry

These values are a composite of the digestion slurry obtained from the bioreactors used in the study.

Table 3: Nitrogen, Phosphorus and Potassium content of digestion slurry

Nutrient	Average content (%)
Nitrogen	1.91±0.02
Phosphorus	2.22±0.21
Potassium	2.84±0.13

DISCUSSION

The first experiment was set up to determine the optimum water hyacinth to water ratio which would allow efficient mixing of substrate and micro-organisms and subsequently result in optimum biogas production (21). The average biogas produced between the different dilution ratios was significantly different ($p<0.05$) and the dilution ratio of 1:4 (water hyacinth: water) resulting in the generation of the highest amount of biogas. This implies that at this ratio there was efficient mixing of the substrate and micro-organisms. Lower dilution ratios generated lower volumes of biogas due

to limited movement and growth of bacteria due to reduced water volume. This resulted in limited mixing of the substrate and micro-organisms and hence the reduced biogas output. Higher dilution rates resulted in diminished biogas output as the substrate quantity became the limiting factor. The optimum dilution ratio of 1:4 obtained in this study is consistent with the observations by Jagadish*et al.* in a study that was published in 2011 (22). In their study Jagadish*et al.* (2011) observed that fermentation slurry of water hyacinth to water in the ration 1:4 resulted in the production of maximum biogas yield. The negligible digester temperature differences show that dilution ratios have no effect on digester temperature. The observed pH in the different digesters (with different dilution ratios) ranged from 5.8 to 8.1 during the course of the study. This range is ideal for biogas production as it provides an ideal environment for hydrolysis and oxidation bacteria (optimum pH range of 4.5 to 6.3) and the methane and acetic acid formation bacteria (optimum pH range of 6.8 to 8.1). This suggests that pH and temperature did not have an effect on the biogas output from the different digesters.

Biomethanation is dependent on the temperature at which the anaerobic digestion occurs as it significantly affects the conversion, kinetics, stability and methane yield and quality (23). This explains why it was chosen as one of the parameters that we were going to investigate in our study. In our study, the effect of temperature on biogas yield and methane content was significant. There was a general increase in biogas yield from $10^{O}C$ to $40^{O}C$. The highest biogas yield was recorded in the temperature range $36^{O}C$ to $40^{O}C$ followed by the temperature range $31^{O}C$ to $35^{O}C$. However, ANOVA comparison between the two incubation ranges indicated that there was no significant differences in the yield ($p>0.05$). This implies that the optimum temperature range for biogas production observed in our study was $31^{O}C$ to $40^{O}C$. This implies that the majority of the methanogens are mesophilic and is consistent with what other researchers have observed (24) and used (4)(25) in their studies. The methane content in the generated biogas decreased with an increase in the incubation temperatures. This is also consistent with observations by other researchers (26) whose results have shown that low digestion temperatures give rise to a reduced yield of biogas that has high methane content. Several explanations have been put forward to try and explain this phenomenon (26) (27)(28) (29). The explanations put forward to explain this phenomenon include: additional production of acetate from homeoacetogens (at the lower temperatures) and methane production due to the activity of psychrophilic methanogens.

Co-digestion of water hyacinth with cow dung at a ratio of 3:1 respectively was shown to improve the yield of biogas and methane content (72% of the total biogas produced). This tallies with results that have obtained in other studies in which methane yield has been shown to be enhanced by co-digestion of water hyacinth with cow dung (30) (31) (32). Co-digestion improves the digestibility of

the substrate through availing additional nutrients to the microbes and the cow dung provides essential microbes (water hyacinth lacks anaerobic bacteria) which enhance the rate limiting hydrolysis process (30) (31).

The nitrogen (N_2), phosphorus (P) and potassium (K) values obtained in our study from the analysis of the liquid digestion slurry are much higher than the values for the organic fertilisers commonly used by small scale farmers in Zimbabwe.

Table 4: Nutrient quality of solid organic fertilisers commonly used by small scale farmers in Zimbabwe*

Fertiliser type	N_2 (%)	P (%)	K (%)
Cattle manure	1.50	0.15	0.78
Leaf litter	1.40	-	-
Anthill soil	0.23	0.05	-
Compost	0.34	0.12	-
Crop residue	0.45	0.06	-
Legumes	1.50	0.08	-
Water hyacinth digestion slurry	**1.91**	**2.22**	**2.84**

*Adapted from (18)

The obtained N_2, P, K values also fall within the range of values cited in literature for organic fertilisers derived from water hyacinth (17) (18) (19).

CONCLUSIONS

Water hyacinths are potentially cheap sources of high quality biogas and organic fertiliser in Zimbabwe.

RECOMMENDATIONS

There is a need to raise awareness amongst different stakeholders on the potential application of water hyacinths as cheap sources of high quality biogas and organic fertiliser.

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Agronomic Strategies For Optimizing Wheat Yields In The South Eastern Lowveld Of Zimbabwe.

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Abstract

Trials to evaluate performance of six wheat varieties sown across different dates and fertilizer levels were conducted at Chiredzi Research Station from 2010 to 2012. Results indicated that variety Smart had the highest mean grain yields (2645Kg/ha) over the years while Sekuru had the lowest yields (1996Kg/ha). Planting early (Early May) had consistently better yields (2930Kg/ha) than late planting (Mid July) which had the lowest yields (1570Kg/ha). The study showed a 269kg/ha wheat grain yield loss for every week's delay in planting from early May. There was a highly significant positive correlation between fertilizer levels and grain yields with the highest fertilizer level (250Kg/ha N) having the highest grain yields (2256Kg/ha). The study concluded that Smart is the highest yielding variety under Lowveld conditions. Farmers are strongly advised to plant in early May for maximum yields. Not more than 150 kg/ha N is recommended for wheat production under Lowveld conditions.

Key Words: agronomic, wheat yields, grain, planting, fertilizer.

INTRODUCTION

Wheat (*Triticumspp*)(1) is a cereal grain originally from the Levant region of the near east and Ethiopian highlands but now cultivated worldwide. In 2009 world production of wheat was 682 million tonnes making it the second most produced cereal after maize (817 million tonnes) and with rice a close third 679 million tonnes (2). Globally, wheat is the leading source of vegetable protein in human food, having higher protein content than either maize or rice the other major cereals. In many countries, wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes breakfast cereal, pasta noodles, fermentation to make beer (3) other alcoholic beverages (4) and biofuel (5). Wheat is a major ingredient in such foods as bread, porridge crackers, biscuits, pancakes, pies, pastries, cakes, cookies, doughnuts and breakfast cereals.

In Zimbabwe wheat is mostly used for baking bread (bread wheat), cakes and biscuits (Durum wheat). It was estimated that the country would produce 20 000 metric tonnes (MT) of wheat in the 2012/2013 year from an area of 10 000 hectares, after 23 000MT was produced from 12 000Ha in the 2011/2012 farming season. Between October 2011 and April 2012, Zimbabwe imported 110 910 MT of wheat from a number of countries that included Argentina, Brazil, Russia and Australia in order to meet domestic demand. Wheat imports for the 2012/13 year are expected to reach 250 000 MT (6). This shows that Zimbabwe will continue to rely on wheat imports to meet consumption requirements. Zimbabwe has produced reasonable amounts of wheat in the past due to intensive research that led to tremendous shift in output from 81 000 tonnes in 1966 to 201 300 tonnes in 1978 (7).

In Zimbabwe, besides factors like poor pricing, unavailability of inputs and electricity for irrigation, low wheat productivity is due to the fact that the crop is grown under sub optimal conditions. Yields in these environments are improved by solving specific production problems (8, 9). Heat stress, drought, poor soil fertility, pre harvest sprouting and frost damage constitute the major abiotic factors that constrain wheat production in Zimbabwe. These constraints have widened the gap between research yields of 8 tonnes per hectare in the Highveld and the national average yield of 2.5 t/ha (10). Agronomy is tasked to constantly update recommendations to make sure that farmers have the latest and correct information. With agronomy, the questions relate to the strategic and tactical management of soil and soil water, the crop planting date, its density, row spacing and fertilization, and the management of biotic stresses, all done so as to maximize economic return at acceptable risk levels. (11).

In most cases farmers fail to plant at the intended dates due to constraints like the unavailability of fuel, late arrival of inputs or late removal of the previous crop in a rotation. In situations like this, farmers need to employ different strategies regarding the types of varieties to use, when they should be planted and the optimum levels of fertilizers to apply as well as the best times and methods of applying these. Yields are usually higher for earlier sowing within the recommended sowing window because early sowing speeds up crop establishment, particularly where frost is not a problem and varieties which flower earlier will have a longer grain filling period. Earlier sowing results in the wheat plant having a higher biomass for increased yield potential where water is not limiting. Planting early also means that a crop can be removed early in the rotation and there is a reduced risk of root diseases (11). The last series of sowing date trials in the lowveld was done in the late 1960's and it is from these trials that recommendations have been based. Results from Experiments done in Lowveld Research Institute at Save Valley showed that highest wheat yields

are obtained with plantings done during the first week of May (12). Wheat varieties have changed several times and this makes it necessary to revisit the sowing date trials.

Research findings from Australia indicated a loss of 200 - 250kg/ha wheat grain yields for each week's delay in sowing time (13). M. Staper and R.A. Fischer (14) reported an average yield decrease of 6 percent per one week delay in anthesis after the optimum sowing date. Highly significant differences in biomass yield which declined with sowing date were also reported. Wheat yields in Australia declined by 35% between May and July Sowings. For Dollarbird wheat, the delay in anthesis was 0.39 days per day sowing was delayed (15).

Nitrogen tends to be the most limiting soil nutrient for wheat (Mwangi, 1995) in Ooro et al (16). It was discovered that the sensitivity of rate and time of N. application was greater in the wheat quality attributes than the grain yield and yield components (16). It was concluded that nitrogen fertilizer could not compensate for the yield reduction in canola and wheat due to sowing late.(17)

Of late, the rainfall seasons have shifted forward and this has resulted in the late planting and harvesting of field crops grown in rotation with wheat. This work intents to come up with a package of recommendations for early and late sown wheat grown in the south eastern lowveld of Zimbabwe in so far as the types of varieties to grow are concerned and the amount of N fertilizer to apply when planting has been early or has been delayed due to constraints in the farming system. The objectives of the study were to determine the yield potential of wheat varieties bred in the private and public sector when they are grown under conditions of the south east lowveld of Zimbabwe, to determine which wheat varieties yield best with early and late sowing and to determine the optimum level of nitrogen fertilizer to apply in early and late sown wheat.

METHODOLOGY

Study area

Two trials were run in the main irrigated block at Chiredzi Research station Zimbabwe, Latitude 21.0203ºS Longitude 31.5727ºE Altitude 431.5 metres above sea level, in the winter of 2010, 2011 and 2012. The soil type is triangle p series (18).

Variety trial

Six wheat varieties available on the Zimbabwean market and bred by the public and private sectors in Zimbabwe were used. The varieties were: Sky, Shield, Stallion, Smart, Sekuru and Nduna. Seed was drilled in rows which were 25 centimetres apart at a seed rate of 120kg per hectare. A basal dressing of Compound D fertilizer with 7:14:7 N, P and K was applied at a rate of 300kg/ha.

Nitrogen fertilizer was applied in the form of ammonium nitrate and this was applied once at a rate of 140kg/ha Nitrogen. Sprinkler irrigation was applied to field capacity after 50% depletion of Available soil moisture (D.A.M.) and scheduling was done using the class A open pan method. The experimental design was a split plot design with Sowing date as the main plot factor and variety the sub plot factor. The gross plot size was made up of six rows in an area 6m X 6m and the net plot size was made up of 4 rows in an area of 12 m^2. Records were taken of emergence date, and grain yield at 12.5% moisture content.

Sowing Dates

Four sowing dates were used in the experiments. The early May sowing was during the first week of May. Three other sowing dates were established after the early May sowing and they were separated from each other by time intervals of two weeks to give a mid June, Late June and Mid July sowing respectively.

Fertilizer trial

The variety stallion was used in the fertilizer trial. Sowing date was the main plot factor and Nitrogen fertilizer level was the sub plot factor. All the nitrogen fertilizer was applied at sowing in the form of ammonium nitrate and the nitrogen levels applied were: 0, 50, 100, 150, 200 and 250 kg/ha **Nitrogen.** Seed rate, row spacing and plot sizes were the same as those for the variety trial. A maintenance dressing of 80kg/ha single super phosphate was applied.

Data collection and analysis

Records were taken for number of tillers (including main tiller) at 28 days after sowing (DAS) (plants were sampled in a metre length at three positions and the average obtained), Days to flowering, days to maturity, number of heads at final harvest (the same positions as above were used), average number of grains per head (Mean of 10 randomly selected heads), 1000 seed weight and grain yield in Kg/ha at 12.5% Moisture content. Results were analyzed statistically using the genestat computer statistical package VSN International 14th edition version 14.1.0.5943.

RESULTS AND DISCUSSION

Varieties

Table 1.shows that over the three year period, wheat variety Smart had the highest mean grain yield of 2645kg/ha and this was followed by Sky with 2405 kg/ha grain yield. The lowest yielding variety when averaged across the years was Sekuru which yielded 1996 kg/ha grain.

In the year 2010 there were no significant differences between the yields of the six wheat varieties. In 2011, Sky had the highest grain yield of 2971kg/ha and variety Sekuru yielded the lowest with 2372 Kg/ha. In the year 2012, Varieties Smart and Sky yielded highest with 3524kg/ha and 3012kg/ha grain yield respectively. The variety Sekuru had consistently low yields across all the three seasons. Smart and Sky are long season wheat varieties and they have a long grain filling period which coincides with cool temperatures at the start of the winter season. This results in them achieving high grain yields. The low yielding varieties were short season varieties.

Table1. Grain yield of six wheat varieties when averaged across four sowing dates at 12.5% Moisture.

Variety/Year	010	011	012	ean
Sky	086	971	012	405
Shield	193	726	226	102
Stallion	078	544	257	009
Smart	245	033	524	645
Sekuru	187	372	459	996
Nduna	305	709	651	256
P	.111	.028	.036	.005

These findings are consistent with results obtained by other workers (17). In the year 2010 there was insufficient water to irrigate the second sowing date at the required time. Irrigation was applied late and this could have resulted in the non significant yield differences observed in 2010. Irrigation was applied as planned in 2011 and 2012 and in these years, significant yield differences between the different wheat varieties were observed.

Sowing Dates

There were highly significant differences ($p<0.01$) in wheat grain yields per hectare between sowing dates when averaged across the three years (Table 2). The early May planting had the highest grain yield of 2930kg/ha and this was followed by the mid June planting which gave an average grain yield of 2540Kg/ha over three years.

Table 2. Mean wheat grain yields obtained at four sowing dates.

Date/Yield(Kg/ha)	010	011	012	ean
Early May	885	476	430	930
Mid June		183	853	540
Late June	280	342	386	902
Mid July	24	903	083	570
P	0.001	0.001	.003	0.001

The lowest mean grain yield of 1570Kg/ha was obtained with the Mid July planting. The early May planting had consistently highest yields in 2010, 2011 and 2012 seasons. On the other hand the Mid July planting resulted in lowest yields in all the years. These results can be explained by the fact that flowering of wheat planted in early May coincided with low winter temperatures that promote grain filling and hence higher grain yields (19, 20). Sowing too late lowers yields as grain fill occurs during increasingly hot and dry conditions. (11).There was a progressive decrease in yield as sowing date was delayed. Over the three seasons, there was a yield reduction of 269kg per hectare for every week's delay in planting (13, 10)

Figure 1.below shows that there was a significant negative correlation between sowing date and grain yield. The correlation equation is: $y = -5559x + 4116$. Which shows that grain yield decreased at the rate of -5559 as the season progressed (15).

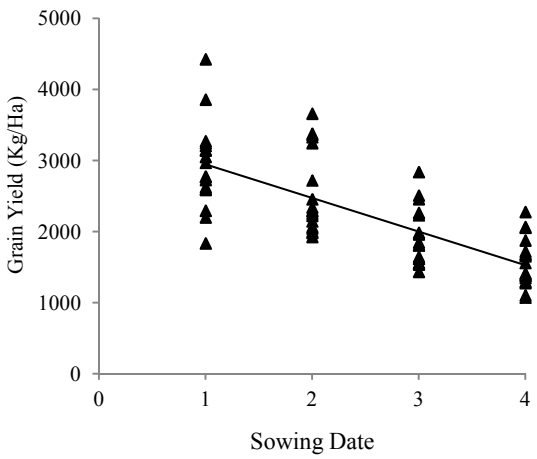

Figure 1.Correlation of sowing date versus Grain Yield.

Fertiliser Level

Mean wheat grain yields over the three years showed highly significant ($p<0.001$) differences between the fertilizer treatments (Table 3). The highest fertilizer level (250kg/ha) produced the highest mean wheat grain yield (2256Kg/ha) which was not significantly different from the yield of 200Kg/ha N (2153Kg/ha wheat grain) and that of 150Kg/ha N (2145kg/ha wheat grain). Averaged over three years, the lowest fertilizer rate, when no N was applied, resulted in the least wheat grain yields (1592Kg/ha). In 2010 and 2012 there were no significant differences between the yields of the different fertilizer levels. However, in 2011 there were highly significant ($p<0.001$) differences in wheat grain yields between the different N levels. In the year 2010, challenges were experienced with the irrigation system and irrigation water could not be applied when it was needed particularly with the Mid June planting. This resulted in the wheat crop not responding to the N fertilizer at the required stage and this had a tendency of lowering the yields and narrowing yield differences between the different fertilizer levels.

Table 3: Effect of fertilizer levels on wheat grain yield in 2010, 2011 and 2012

Nitrogen (Kg/ha)/Year	010	011	012	ean
0	086	243	447	592
50	193	122	529	948
100	078	285	504	956
150	245	520	671	145
200	187	513	759	153
250	305	590	874	256
P	.261	0.001	.746	0.001

The responses obtained in 2011 and 2012 were as expected (16). Results obtained after analyzing the means over the three seasons are consistent with current recommendations of 140kg/ha N. Figure 2 below shows that applying more than 150 kg/ha N will not result in higher wheat grain yields.

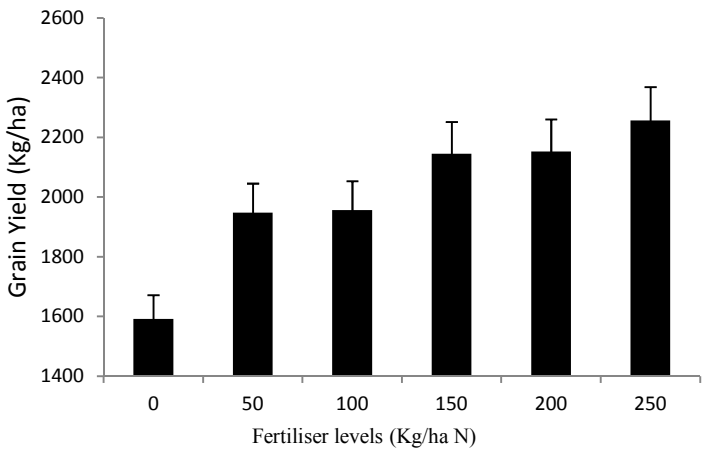

Figure 2: Wheat Grain Yield (Kg/ha) at 12.5% Moisture Content

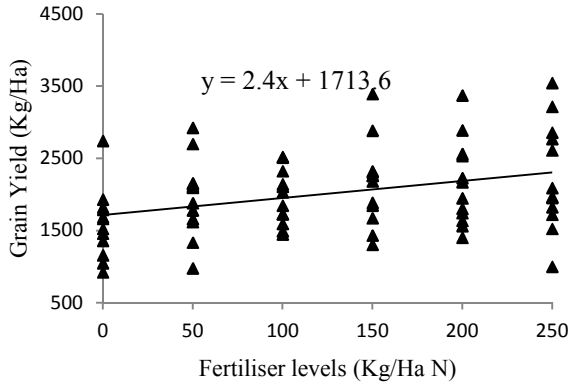

Figure 3. Regression between Fertilizer level and grain yield

The relationship between fertilizer level and grain yield can be best be explained by the regression equation

$y = 2.4x + 1714$ (figure 3).

CONCLUSIONS

From the Results of experiments carried out over three seasons, it can be concluded that long season varieties (Smart and Sky) were the highest yielding. The lowest yielding wheat variety when averaged across the three years was Sekuru. The early May Planting produced the highest yields in all the years.(11, 8, 21). The lowest grain yield was obtained with the mid July planting. An average of 269Kg/ha wheat grain yield per hectare is lost with every week's delay in sowing. (13, 14). Applying more than 150kg/ha Nitrogen will not result in any significant increase in wheat grain yield in the south east lowveld of Zimbabwe.

RECOMMENDATIONS

From the results of trials carried out in 2010, 2011 and 2012, farmers in semi arid natural region 5 of Zimbabwe (South East Lowveld) are advised to grow wheat varieties Smart and Sky as early as possible in the month of May in order to obtain maximum grain yield. In situations where wheat planting has been delayed, the variety Sekuru is recommended since it yields constantly across early and late sowings. Recommended rates of nitrogen fertilizer (150kg/ha) should be used with both early and late sowings of wheat since no yield advantage is derived by increasing fertilizer application rates in late sowings or reducing N fertilizer rate with early sowings.

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Improvement of seed size in cowpea (*Vignaunguiculata*[L.]Walp.)through mutation breeding

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Abstract

The main objective of the cowpea (*Vignaungucuilata*[L] Walp) improvement program in Zimbabwe has mainly been to develop high yielding early maturity, bushy type varieties and this has been well achieved. However, cowpea consumers prefer the large seeded cowpeas and only landraces have this trait. Attempts were made to improve seed size in the high yielding early maturing bushy type cowpea variety, CBC1 using gamma rays induced mutagenesis. 200 g (approximately 1 600) seeds treated with different doses (0, 100, 150, 200, 250 and 300 gy) of gamma rays were planted in the field and the dosimetry studies conducted in order to establish the optimal doses which were found to be 150 gy, 200 gy and 250 gy. A range of morphological and physiological mutants were observed in M2 through to M5. True breeding mutant lines were selected and subjected to replicated agronomic trials at M6. After three seasons of testing, striking mutants showed highly significant differences in seed size. 10 mutant lines exhibited seeds bigger than those of CBC1 used as check, however there were no significant differences in yield. In the seasons 2010/11 and 2011/12, the line 'cm/150/m6-2' had 699.9 and 676.9 seeds for 100 g weight respectively compared to CBC1 which had 774.4 and 745.6 seeds in 100 g weight respectively. The study clearly demonstrated that mutation breeding is a faster and a viable method for introducing desired traits in improved varieties.

Key Words: **Cowpea, Mutants, Mutagenesis, Seed size, Gamma irradiation**

INTRODUCTION

Cowpea is ranked fourth in production and consumption among legume crops grown in Zimbabwe. Nearly 90% of smallholder farmers produce cowpea for their own consumption and for sale at local and urban markets (1). Production is centred mainly in the arid and semi-arid areas of the country where it is an essential component of their cropping systems as it plays important roles in biological nitrogen fixation, crop rotations and relay cropping (2). Cowpea is utilised in various forms; for human nutrition as immature green pods, green leaves, dried mature grain, cowpea porridge and dried leaves and for livestock feed as dried fodder (1). The crop forms the base of dietary supply of

nutritional elements and household food security for the smallholder farmers, who constitute about 70% of the total Zimbabwean farming community.

Genetic variability forms the basis of crop improvement. In crop breeding it can be observed as a natural occurrence or experimentally generated by crossing/hybridization, mutagenesis and gene transfer (3). In fact, naturally, cross pollinating crops are highly diverse as opposed to self pollinating crops. Cowpea is highly self-pollinating hence limited genetic variation exists in the midst of its germplasm. The use of mutagens in crop improvement dates back to crop domestication (3). Mutagenesis continues to offer unique opportunities for crop improvement and its application has generated a vast amount of genetic variability leading to a worldwide release of more than 2,700 varieties of cereals, pulses, oil, root and tuber crops, and ornamentals (4).

Technically, plant materials are treated with physical or chemical mutagens such as gamma rays, ethyl methane sulphate (EMS), and mutated sub-sequent populations are screened in the field for variation in morphological traits or in the laboratory for variation in chemical components and for the possible characterization of genetic changes using the appropriate molecular technologies. Mutants are alternatives or exceptions to the normal state of the gene/chromosome structure and indeed, these exceptions provide the variation for selection of new and useful types of plants as well as the basis for evolution. A desired mutation in a good genetic background is a very attractive component in breeding programmes.

The mutation breeding approach is simpler and faster than crossing with an exotic source for a desired trait. In addition, the technique is very important in cases where there is little genetic diversity and crosses are difficult to make. Some legume crops such as bambaranut, common bean, cowpea and groundnuts suffered a genetic bottleneck during domestication which resulted in narrow genetic bases. It is difficult to find diverse parents for particular traits such as seed size, to use in a crossing programme for cowpeas. Therefore mutation breeding offers a good opportunity for introduction of some desirable agronomic and quality traits in cowpea and these other legumes. The main objective of the study was to increase seed size in CBC1 and evaluate the retention of other good agronomic traits of the variety.

METHODOLOGY

Cowpea seed of CBC1 variety was irradiated with gamma radiation (100gy, 150gy, 200gy, 250gy and 300gy) in Vienna in 2002 under a collaborative research project between International Atomic Energy Agency (IAEA) and Crop Breeding Institute (CBI) in Zimbabwe. Each pack of

approximately 4 000 seeds (500 g) were subjected to a single dose of gamma rays at the following levels; 100gy, 150gy, 200gy, 250gy and 300gy. The irradiated seeds, designated M1 in the different doses were planted at Harare Research Station in 2002 to give the M1 plants that gave rise to M2 seeds. Approximately 1 600 M1 seeds were planted in two replications for each dose treatment. 1 000 M1 plants were selected and 30 seeds were planted from each selected plant on a plant to row basis giving 30 000 M2 plants in 2003/04 season. Most albino and inferior plants were observed in the 100gy and 300gy (figure 1).

Figure 1: Albino effects observed in genotypes exposed to 100gy and 300gy

Selection started at M2, putative mutants were advanced to M3, M4, M5, M6 and M7 in subsequent seasons. The best mutants were selected while the poor and inferior mutant lines were discarded. Selection was mainly on the basis of phenotypic expression and performance. Preliminary yield trials and good agronomic characteristics were considered in the initial evaluations at M2 and M3. These Initial observations and selections showed that doses 100gy and 300gy were not ideal for the survival and good agronomic performance of the mutants. Most of the promising mutants were in the dosage range of 250gy and a few were found in the 150gy and 200gy categories.

Table 1 Mutant genotypes and controls used in the trials

enotype	Genotype Code	Attribute	Gamma Ray Dosage (gy)
1	cm/200/m6-2	Mutant	200
2	cm/200/m6-1	Mutant	200
3	cm/150/m6-2	Mutant	150
4	cm/250/m6-1	Mutant	250
5	cbc1	Parent	0
6	cm/250/m6-2	Mutant	250
7	cm/200/m6-3	Mutant	200
8	cm/250/m6-4	Mutant	250
9	cm/250/m6-7	Mutant	250
10	cm/250/m6-6	Mutant	250
11	cbc2	Check	0
G12	cm/150/m6-1	Mutant	150
13	cm/250/m6-5	Mutant	250
14	cm/250/m6-3	Mutant	250
15	cm/200/m6-4	Mutant	200
16	cm/150/m6-3	Mutant	150

15 mutant lines (Table 1) were selected at M7 in 2007 and these were tested for good agronomic performance in 3 seasons at 3 sites; Harare Research Station, Gwebi VTC and Kadoma CPU. Trials were designed in a randomised complete block design (RCBD) with 4 replicates at each site. The mutants were evaluated primarily for seed size and other agronomic traits. CBC1 was used as the parental control variety. Table 2 shows characteristics of the testing sites.

Agronomic data was taken for: number of days to 50% flowering, response to diseases (scab, ascochyta blight, bacterial blight and virus), number of pods per plant, number of seed per pod, days to 95% maturity, seed size, pod yield and seed yield. Phenotypic data was subjected to analysis of variance through Genstat Discovery, Version 7 software. Correlations among traits were also analysed through the same software.

Table 2Description of the testing sites

Site	Natural Region	Latitude	Longitude	Latitude (m)	Average Rainfall (mm)	Average Temperature (^{0}C)
Harare Research Station	a	$7^0$48'S	$1^0$03'E	3506	00	25
Gwebi VTC	a	$7^0$41'S	$0^0$32'E	3448	00	25
Kadoma CPU	b	$8^0$19'S	$9^0$53'E	2149	00	30

RESULTS AND DISCUSSION

Across site statistical analysis of data for the 2009/10, 2010/11 and 2011/12 seasons at Harare, Gwebi and Kadoma clearly showed consistent significant variations ($p<0.05$) in seed size. (Table 3)

Table 3 Analysis of Variance for Seed Size for 2009/10, 2010/1 and 2011/12

eason	ource	F	SS	S	TSS	pr
009/10*	ocation		1130992	65496	2.4	.001
	enotype	5	256774	7118	4.1	.001
	L	0	426052	4202	3.5	.001
	otal	7	1813818	96816		
010/11+	ocation		389182.5	89182.5	2.3	.001
	enotype	5	75844.8	056.3	4.1	.001
	L	5	73466.2	897.7	3.6	.001
	otal	1	538493.5	99136.3		
011/12+	ocation		61952	1952	9.5	.001
	enotype	5	109963.3	330.88	4.7	.001
	L	5	145067.8	671.18	5.8	.001
	otal	1	316983	8954.06		

*data for Harare, Gwebi&Kadoma, +data for Harare &Gwebi

In 2009/10 and 2010/11 seasons most of the variation came from the location and a little came from the treatments and the interactions. The ratios are 14.1%, 62.4% and 23.5% respectively for 2009/10 and 14.1%, 72.3% and 13.6% respectively for the 2010/11 season. Differently, 2011/12 season showed more variation coming from G*E interaction (45.8%) and genotype (34.7%). Location had the least contribution (19.5%) to variation.

Mutation induction can be utilized to supplement conventional plant breeding (5). CBC1 is a small seeded variety. This study has demonstrated that through induced mutagenesis it can be improved into a large seeded variety to meet the requirements of the local consumers. In 2009/10 season

CBC1 had an average of 736.4 seeds in a 100g weight whilst 10 mutants showed greater improvement ($p<0.05$) in seed size, these include cm/200/m6-3 (645.2 seeds), cm/200/m6-1 (670.4 seeds), cm/250/m6-1 (707.1 seeds) and cm/150/m6-3 (707.9 seeds) in a 100g weight (Table 4).

Table 4 Number of Seed in 100g Weight for: 2009/10 – 2011/12 Seasons

	2009/10 Season	2010/11 Season	2011/12 Season
Genotype			
cm/200/m6-2	714.4	754.5	767.5
cm/200/m6-1	670.4	720.4	741.75
cm/150/m6-2	784.2	699.9	676.88
cm/250/m6-1	707.1	746.4	779.75
cbc1	736	774.4	745.62
cm/250/m6-2	793	782	788.88
cm/200/m6-3	645.2	762.2	741.75
cm/250/m6-4	722	774.6	777.88
cm/250/m6-7	746.4	785	730.62
cm/250/m6-6	721.8	725.1	719.12
cbc2	815.7	794.9	742
cm/150/m6-1	746.2	755.6	702.62
cm/250/m6-5	718	740.2	724.12
cm/250/m6-3	749	755.6	738.88
cm/200/m6-4	766.7	755.2	761.25
cm/150/m6-3	707.9	749.9	709.38
Mean	734	754.9	740.5

The same superior performance by mutant lines over the parent was also expressed in 2010/11 season. CBC1 produced 774.4 seeds in a 100 g weight sample whereas the following mutants gave the respective numbers; cm/150/m6-2 (699.9 seeds), cm/200/m6-1 (720.4 seeds), cm/250/m6-6 (725.1 seeds) and cm/250/m6-5 (740.2 seeds). In the 2011/12 season the best performers on seed size were cm/150/m6-2 (676.9 seeds), cm/150/m6-1 (702.6 seeds), cm/150/m6-3 (709.4 seeds) and

cm/250/m6-6 (719.1 seeds). These out performed CBC1 which had 745.6 seeds in 100g weight as show in table 4.

Table 5Analysis of Variance for Yield for Harare &Gwebi VTC 2011/12

Season	Source		S	MS	TSS	pr
2011/12	Location		5901096	5901096	8.3	.001
	Genotype	5	1542576	102838	7.8	.09
	GL		1199559	79971	3.9	.257
	Total		8643231	6083905		

Analysis of variance for yield data showed that mutants performed within range of the parent CBC1 in all the 3 sites. There were no significant differences on yield ($p>0.05$) between the mutants and the parent (Table 5). Mutagenesis can therefore be used to target the improvement of only one trait and this is simple and faster than the conventional backcross method (5). As stated by Ceccarelli*et al*., (3), a desired mutation in a good genetic background is a very attractive component in breeding programmes. The method is very successful for self pollinating crops because they generally show little natural variability to be used for improvement through conventional breeding techniques in concurrence with previous studies (6).

1 **Table 6 Mean Yield Levels for Harare & Gwebi VTC for 2011/12 Season**

Genotype	Gwebi VTC	Harare	Means
cm/200/m6-2	842	968	905
cm/200/m6-1	881	1270	1076
cm/150/m6-2	670	1211	941
cm/250/m6-1	697	1143	920
cbc1	874	1406	1140
cm/250/m6-2	866	1452	1159
cm/200/m6-3	910	1079	994
cm/250/m6-4	684	1170	927
cm/250/m6-7	108	1181	1120
cm/250/m6-6	812	1354	1083
cbc2	120	1356	1278
cm/150/m6-1	699	1388	1043
cm/250/m6-5	833	1414	1124
cm/250/m6-3	849	1369	1109
cm/200/m6-4	893	1610	1251
cm/150/m6-3	878	1146	1012
Mean	853	1282	1068
LSD			89.1

Table 6 shows the mean yield levels for the mutants against CBC1 and the check CBC2 for the 2011/12 season at two sites, Gwebi VTC and Harare Research Station. At Harare the highest yielder was cm/200/m6-2 (1 610 kg/ha), however its yield was not significantly different ($p>0.05$) to any of the genotypes including the parent CBC1 and the check CBC2 which had 1 406 kg/ha and 1 356

kg/ha respectively. The mean yield figures showed that highest yield figures were in the dose range 200gy, cm/200/m6-4 had a mean yield of 1 251 kg/ha which was very close to the best yielder cowpea variety CBC2 which had 1 278 kg/ha (Table 6).

The lines cm/200/m6-1, cm/150/m6-2, cm/150/m6-3 and cm/250/m6-6 were the common high performers on seed size. They showed superior performance in all the seasons in which they were tested. In 2011/12 season cm/200/m6-1, cm/250/m6-6 and cm/150/m6-3 showed good correlation of their seed size with yield potential, even though there were no significant differences on yield, their numeric mean yield figures were high, 1 076 kg/ha, 1 083 kg/ha and 1 012 kg/ha respectively, much closer to the parent CBC1 which had a mean of 1 140 kg/ha.

CONCLUSION

Currently all the commercial cowpea varieties in Zimbabwe are small seeded, whilst the demand for larger seeded varieties increases. These research efforts have shown that seed size can be easily and rapidly increased by gamma irradiation mutation breeding. In terms of yield, all the mutants performed within the same range as the control CBC1. Thus, lines such as cm/200/m6-1, cm/150/m6-2, cm/150/m6-3, cm/250/m6-6 and cm/200/m6-4 that have shown improved seed size due to mutation induction can be released into the formal seed system to meet the demand for larger seeded cowpea varieties.

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Local perceptions of livestock grazing and rangeland degradation in communities adjacent to the northern Gonarezhou National Park, Zimbabwe

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Abstract

This study evaluated the perceptions of local people living adjacent to a state protected area in southeastern Zimbabwe on the dynamics of livestock grazing and rangeland degradation. A total of 236 respondents were interviewed and a large herbivore aerial survey in northern Gonarezhou National Park was conducted. About 30% of the respondents reported that livestock was grazed inside the Gonarezhou National Park, both in the dry and wet seasons. Overall, 72% of the respondents perceived that there was some rangeland degradation whereas 28% of the respondents perceived that there was no noticeable rangeland degradation in the study communities. The results of the aerial survey showed that livestock encroached into Gonarezhou National Park, and grazed about 15 km deep into the park in the dry season. Strategies that minimize livestock encroachment into protected areas and ensure the continued existence of productive rangelands are urgently required in semiarid savanna environments.

Key Words: perception, livestock grazing, rangeland.

INTRODUCTION

Livestock grazing in protected areas, communal areas and rangeland degradation, together with associated decreases in palatable species and increase in soil erosion, is a worldwide problem (1-4). For instance, increasing grazing pressure, associated not only with large livestock like cattle (*Bostaurus*), but also with small stock like goats (*Capra hircus*) and sheep (*Ovisaries*), when combined with human activity on natural forests can increase woodland and land degradation (5, 6). Moreover, the perception that environmental change is occurring at accelerated rates due to human mismanagement of natural resources, in the form of land degradation is an important force driving

development policy and interventions in semiarid and arid environments in Africa (7). Scientific expertise has been at the forefront of large-scale and local attempts to reduce or reverse the impact of degradation, however, more recently the importance of involving indigenous knowledge, and the people actually experiencing and being affected by land degradation, in the decision-making process, has been acknowledged (7).

Pastoral or local communities usually have a detailed knowledge of their surrounding environment and grazing lands. This knowledge is gained through continuous herding and is supplemented by the knowledge accumulated from historical land use (8, 9). Herders gauge knowledge of land degradation in terms of production performances of livestock, and these are invariably related to the status of the soils and key forage plant species (10). Furthermore, pastoralists or herders, by experience, can usually estimate the trend of their pastures through the years. They generally know what species and in what quantity decreased or increased in total and hence, recognise that degraded environments are not suitable for livestock grazing (10, 11). Overall, herders combine both ecological, e.g. plants and soils, and livestock production indicators, e.g. milk yields, calving rates and general animal health, as proxies for assessing degradation of the grazing lands (12).

Sedentarization of pastoralists, whether forced or spontaneous, has resulted in severe land degradation in the semiarid zones (13). The pattern of anthropogenic land degradation is much more severe around permanent settlement sites than it is in open rangelands because of concentration of pressure such as deforestation, overcultivation and overgrazing (14, 15). Decreased mobility of animals' means increased continuous grazing around the settlements, resulting in reduced vegetation diversity and soil degradation. At the same time, lower grazing pressure in distant pastures results in an invasion of unpalatable plants. Environmental degradation can result from the excessive removal of vegetation through grazing or harvesting of fodder and the tillage of some soils using animal traction. The reduction and degradation of common pastures have led livestock owners to increasingly rely on crop residues, purchased feeds (15) and tubers of shrubby legumes (16).

Rangeland may be considered as land with vegetation having important use for livestock grazing due to availability of forage (17). Plant characteristics and ecosystems have evolved to facilitate their survival in arid and semiarid environments. However, due to ever-increasing livestock and human populations, arid and semiarid lands all over the world are overexploited and, hence, are under immense pressure (17). Patterns of ecological change, notably increased bush dominance, have been linked to increased cattle-grazing intensity, but it remains contentious whether these

changes represent land degradation (18). Uncertainty in ecological understanding stems from the dynamic, nonequilibrium functioning of semiarid ecosystems (18, 19). Nonequilibrium ecological theories are founded on the identification of the inherent dynamism of dry land ecosystems, where rainfall plays a greater role in plant growth than variations in grazing regimes (20). According to this theory, shifts in vegetation cover and composition between wet and dry seasons represent not degradation, but rather evidence of fluctuating rainfall (12, 19). Vegetation cover and species composition decline when grazing is heavy and sustained and improve with increased precipitation and reduced grazing pressure. Such changes reflect what is called 'ecological resilience' (21). In nonequilibrium ecosystems, pastoral land use is closely tied to vegetation dynamics, which in turn are greatly influenced by climatic variability to which pastoralists respond using mobility. Under excessive anthropogenic pressures, the resilience threshold is exceeded, resulting in land degradation (12).

In contrast, the equilibrium model stresses the importance of biotic feedbacks such as density-dependent regulation of livestock populations and the feedback of livestock density on vegetation composition, cover and productivity (22, 23). Range management under this model centres on carrying capacity, stocking rates and range condition assessment (23). Recent studies suggest that most arid and semiarid rangeland systems encompass elements of both equilibrium and nonequilibrium dynamics at different scales, and that management needs to take into account temporal variability, spatial heterogeneity and climate variations (23). Accordingly, state and transition models have been formulated to explain the likely habitat changes brought about by temporary variability (24). These models suggest that dry land ecosystem dynamics can be described by a set of discrete states of the vegetation community, and a series of distinct transitions between states. State and transition models imply that environmental changes can occur very

rapidly and may be triggered by management actions, such as increased cattle-stocking levels or managed burning, and/or by natural events including rainfall variability and fire (18, 24).

Objectives

The main objective of this study was to establish the perceptions and knowledge of local people about livestock grazing and rangeland degradation in communities adjacent to the northern Gonarezhou National Park, southeast Zimbabwe. Moreover, we also sought to determine the extent of livestock grazing during the dry season in Gonarezhou National Park and the long-term rainfall trends in the study area.

METHODOLOGY

Study area

This study was based on data collected from eight villages occurring in four wards, namely, Chibwedziva and Chizvirizvi falling under Chiredzi district, and Mtandahwe and Mahenye falling under Chipinge district, adjacent to the northern Gonarezhou National Park, southeast Zimbabwe (Figure 1). Local residents in communities adjacent to the northern Gonarezhou National Park practice a combination of subsistence, cash crop farming and livestock production. Livestock species include cattle, sheep, and goats and are generally used for either commercial animal production or for subsistence farming (9). The savannas of the study area are dominated by *Colophospermummopane*woodlands (25). The neighboring Gonarezhou National Park is the second largest national park in Zimbabwe covering an area of about 5053 km^2 in southeast Zimbabwe, between 21° 00′–22° 15′ S and 30° 15′–32° 30′ E. The study area lies in a semiarid savanna ecosystem with an average annual rainfall of between 400 and 600 mm (25). The Gonarezhou National Park ecosystem is endowed with a wide variety of both large carnivores and herbivore species (9). Gonarezhou National Park is largely unfenced and hence animals move in and outside of the park to the adjacent communal areas.

Data collection

Data were collected using a semi-structured questionnaire (see Appendix 1) that was administered to 236 randomly selected local people from eight study villages through interviews. The sample included 146 (62%) males and 90 (38%) females. In this study, we used the general perceptions and knowledge held by local people on livestock grazing for the assessment of land degradation based on availability of forage resources and state of grazing areas. Data were collected from December 2010 to May 2011. The household heads or another permanently resident adult (≥18 years) were targeted as the respondents that took part in the interviews in the respondents residence. Interviews were carried out in Shangaan and English. Pre-testing was conducted in a village occurring outside the study communities to ensure that all questions were clear, and a final version was prepared for sampling. Each interview took about 30 minutes to complete.

Moreover, an aerial survey was conducted in October 2012 to gather the current data on livestock grazing in GonarezhouNational Park using a Cessna 185 aircraft. The survey area was approximately 700 km^2, i.e. 500 km^2 in northern Gonarezhou National Park and 200 km^2 in north-western GonarezhouNational Park. We only searched for large herbivores (> 20 kg in body weight) both domestic and wild. The aerial surveys were conducted over two days in the afternoon on both occasions. The average maximum temperature for the survey days was 29 °C and with good

visibility. The aircraft flew at about 100 m above the ground with an average speed of 160 km/hr. Animal sightings were recorded and their location gathered using a Garmin 60 Global Positioning System (GPS) Unit receiver. More details of similar total livestock and wildlife aerial surveys in GonarezhouNational Park are provided by Gandiwa et al. (26). Data on rainfall for the study area was retrieved from historical rainfall records kept at Chipinda Pools in northern GonarezhouNational Park.

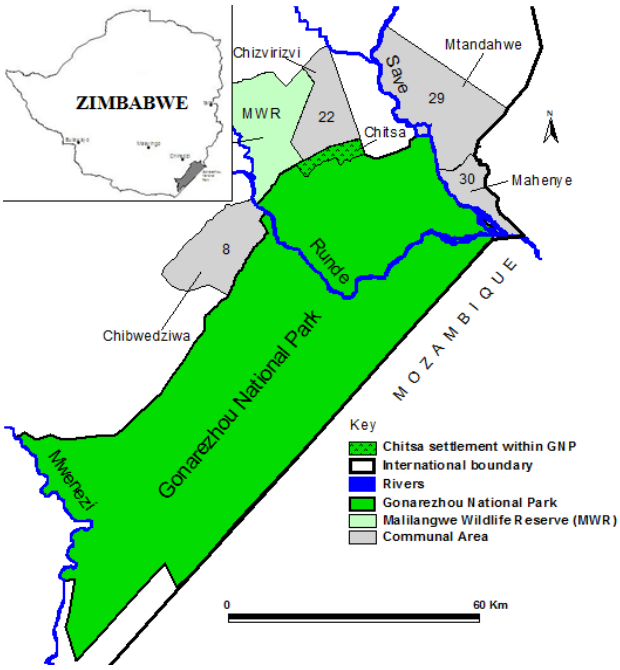

Figure 1: Location of the four study wards adjacent to the northern Gonarezhou National Park, southeast Zimbabwe. Note: Numbers represents ward numbers. Source: (9)

Data analysis

Data were analysed using the Statistical Package for Social Sciences for Windows version 19 (SPSS Inc., Chicago, IL, USA). Collected data were summarised using descriptive statistics. Chi-square (χ^2) tests were used to analyse responses on livestock ownership, grazing and rangeland degradation. Differences were considered to be significant at $P \leq 0.05$. Livestock distribution data were spatially represented using ArcView 3.2 software for Windows (ESRI, Redlands, CA). Simple linear regression was used to analyse rainfall trends over time.

RESULTS

Cattle ownership and grazing dynamics

There was a significant increase in the number of cattle owned by local people in the period 2001 to 2010 (χ^2 = 11.43, df = 3, P = 0.010), with the majority of respondents having between 1 and 10

cattle (Figure 2). In terms of livestock grazing, the majority of respondents reported that livestock was mostly grazed in the communal grazing areas within the villages and wards. The availability of enough grazing pastures (n = 116, 49%) in the wet season and availability of crop residues in the dry season (n = 148, 63%) were given as the main reasons why livestock was commonly grazed in the villages and wards (Tables 1 and 2). However, a smaller proportion of respondents reported that they grazed livestock in both the communal grazing areas within the villages and inside the adjacent GonarezhouNational Park (Figure 3). There was no significant difference in responses with preferred areas for livestock grazing with season (χ^2 = 0.59, df = 2, P = 0.744).

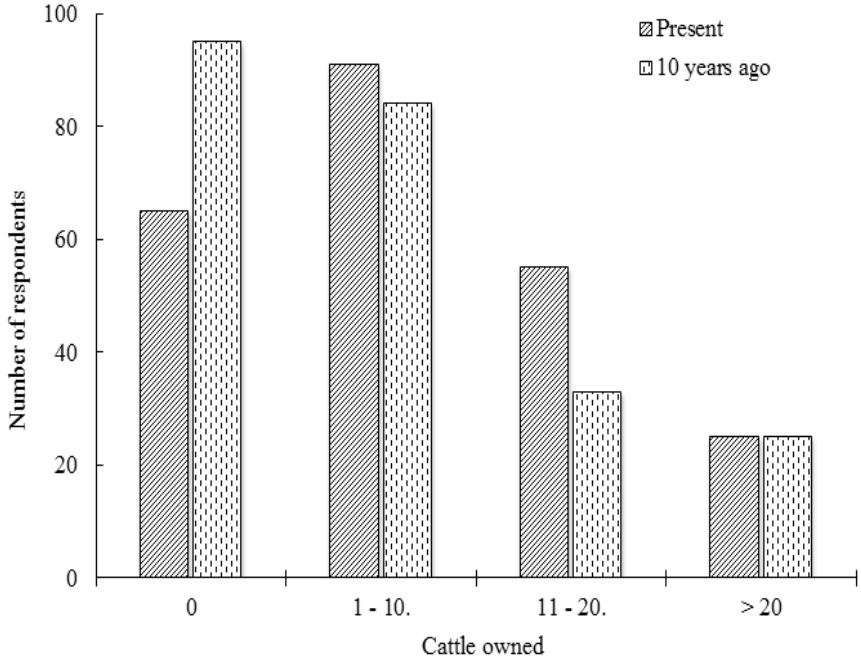

Figure 2: Cattle ownership by the 236 respondents in communities adjacent to the northern Gonarezhou National Park, Zimbabwe. Notes: Present denotes as at December 2011; 10 years ago denotes as at 2001

Perceptions of land degradation

About 72% (n = 170) of the respondents perceived that the rangelands had been degraded due to expansion of settlements and fields (n = 64, 27%), and increase in human and livestock populations (n = 63, 27%; Table 3). In contrast, the remaining 28% (n = 66) of the respondents perceived that the rangelands had not been degraded (χ^2 = 44.96, df = 1, P< 0.0001). Furthermore, about 65% (n = 153) of the respondents reported that veld fires in the rangeland had decreased in the communities whereas 25% (n = 57) of the respondents reported that they was an increase in veld fires in the rangelands within the community and lastly, only 11% (n = 26) of the respondents reported that

occurrences of veld fires in rangelands had remained the same within the communities (χ^2 = 111.47, df = 2, P< 0.0001).

Table 1: Explanations given for areas where livestock are grazed during the wet season in northern GonarezhouNational Park ecosystem, Zimbabwe. Total percentage exceeds 100 because the respondents were allowed to give multiple answers

Area	Number of responses	%
Within the village and ward		
Enough grazing pastures	116	49
Safe from predators	31	13
Area livestock should legally grazed	30	13
Good security of animals	14	6
Less diseases	10	4
Within the protected area		
Good and undisturbed pasture inside the park	57	24
Too many cattle and overgrazing within the communities	5	2
No other area to graze livestock	2	1
Crops in the fields within the communities	1	1

Table 2: Explanations given for areas where livestock are grazed during the dry season in northern GonarezhouNational Park ecosystem, Zimbabwe. Total percentage exceeds 100 because the respondents were allowed to give multiple answers

Area	Number of responses	%
Within the village and ward		
Existence of crop residues	148	63
Safe from predators	26	11
Good security of animals	23	10
Enough pasture	2	1
Low diseases	2	1
Within the protected area		
Enough pasture throughout the year	64	27
Shortage of water in the villages	17	7
No other grazing area to graze livestock	8	3

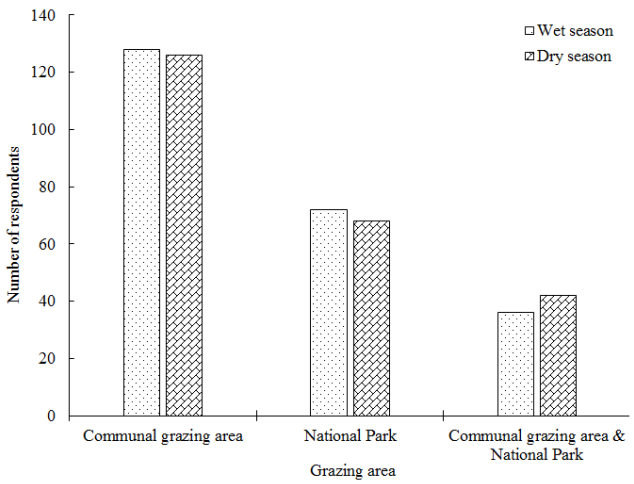

Figure 3: Areas where livestock is grazed by season (wet and dry) as reported by the 236 respondents in communities adjacent to the northern Gonarezhou National Park, Zimbabwe

Table 3: Explanations given for the perceived trend in land degradation in communities adjacent to the northern Gonarezhou National Park, Zimbabwe

Explanation	Number of responses	%
Perceived occurrence of land degradation		
Expansion of households and fields in the village and ward	64	28
Increase in human and livestock population	63	27
Continuous grazing in same areas (poor forage)	25	11
Destruction of trees and grass	5	2
Immigration of livestock from other wards	4	2
Veld fires	2	1
Drought	2	1
Soil erosion	1	1
Perceived non-occurrence of land degradation		
Enough grazing area within the village and wards	24	10
Low livestock numbers	19	8
Good conservation of natural resources	16	7
Good farming practises	5	2

Livestock grazing within GonarezhouNational Park

Livestock were recorded about 15 km within the GonarezhouNational Park from the north-western border of the park in October 2012 (Figure 4). The majority of the counted animals were cattle (4241), followed by shoats (sheet and goats) (1192); elephant *Loxodontaafricana* (106); impala *Aepycerosmelampus* (95); buffalo *Synceruscaffer* (62); kudu *Tragelaphusstrepsiceros* (32); donkey *Equusafricanusasinus*(5); giraffe *Giraffacamelopardalis* (5), and wildebeest

Connochaetestaurinus(2). In the northern GonarezhouNational Park, no livestock was recorded within the park beyond the park control fence/boundary. It was evident from the air that much of the forage resources were inside GonarezhouNational Park than in the adjacent communal grazing areas thereby leading to the influx of livestock into the park.

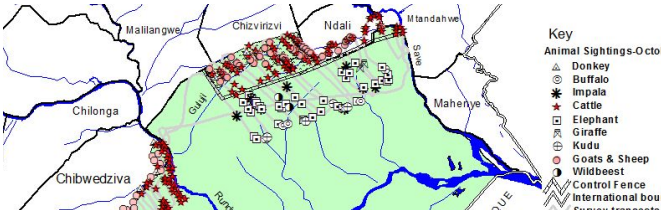

Figure 4: Animal sightings (livestock and wildlife) within and adjacent to Gonarezhou National Park, Zimbabwe, October 2012

Annual rainfall trends

For the period, 1969–2011, mean annual rainfall for the northern GonarezhouNational Park ecosystem was 485 mm (standard deviation = 195 and variation = 40%; Figure 5). There was no significant relationship between rainfall and year ($r = 0.08$, $R^2 = 0.01$, $F_{1,41} = 0.26$, $P = 0.614$).

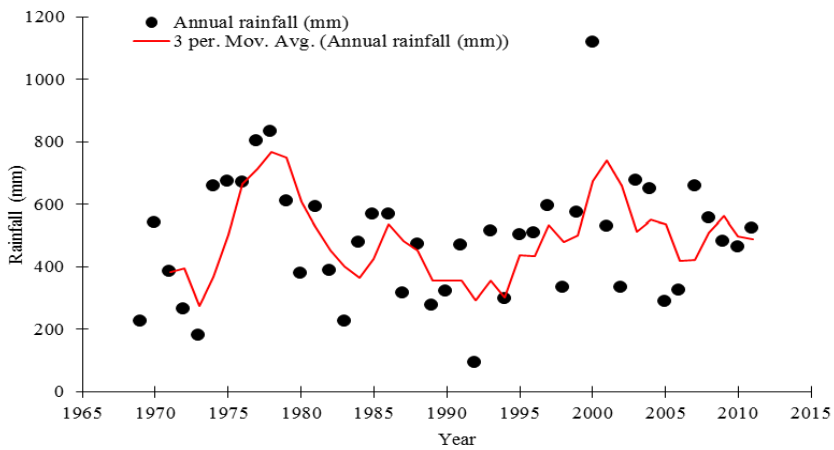

Figure 5: Annual rainfall trends (together with 3 year moving average) for the northern GonarezhouNational Park ecosystems, Zimbabwe, 1969–2011. Data are from Chipinda Pools rain station in GonarezhouNational Park

DISCUSSION

Our results showed that local people generally perceived that there was some degradation of rangelands primarily due to: i) continuous grazing in same areas thereby negatively affecting forage resources, ii) increasing human and livestock populations, and iii) expansion of fields and settlements. Our findings give insights on the status of rangelands in the semiarid rangelands occurring in southeast Zimbabwe. The Zimbabwean Government has based rangeland policies on conventional interpretations of rangeland degradation based on the following: soil erosion; changes in soil structure; decreases in palatable and nutritious plant species, and increases in unpalatable and non-nutritious; decreases in perennial grasses, and increases in annuals; shrub encroachment; decline in the quality and quantity of forage; decline in the primary and secondary productivity of rangeland, and decline in the welfare of herd-owners (27). Elsewhere, in Borana zone of southern Ethiopia, local people considered the condition of the rangelands to have declined dramatically over time due to bush encroachment and recurrent droughts (28). Continuous grazing in semiarid rangelands can lead to loss of vegetation with negative, long-term effects on grass functional qualities and forage production (29). A less well-known, more subtle, yet wide spread form of range land degradation is encroachment by generally unpalatable trees and shrubs at the expense of palatable grasses over a time span of several decades (7, 30).

In line with our research findings, African rangelands are commonly perceived as undergoing widespread and serious degradation mainly through human population increase and associated land-use impacts.

However, this view has been much debated and called into question based on different interpretations of indicators of degradation and insufficient research. In many areas under communal tenure in southern Africa the apparently deleterious effects of degradation through heavy grazing by domestic livestock and fuel wood harvesting appear equally contentious (31). Heavy stocking rates could adversely affect woody plant and grass productivity, soil fertility, the hydrological cycle, erosion rates, and dam siltation rates (19). Consequently, environmental degradation of savanna ecosystems has been seen as one of the main factors leading to the increased vulnerability of African pastoral and agro-pastoral economies (30), and hence, efforts should be put to minimise environmental degradation.

We recorded that there was a slight increase in the cattle owned by local people in this study. It has been reported that high populations of livestock have been maintained in the communal areas of

Zimbabwe for the past half century and for most of this time have been significantly in excess of the officially recommended stocking rates (32). However, populations of livestock decreased in drought years, e.g. 1983 and 1991–92, whereas they increased in the periods with normal rainfall. Livestock mortality is often high in the communal areas during droughts, unless animals either have access to key resource areas or are provided with supplementary feed. In our case, we recorded that local people fed livestock with crop residues in the dry seasons. In the semiarid communal rangelands, croplands provide important resources during the dry season in the form of crop residues and patches of grass (33). In the past, communal pastoralists in the highly variable, arid and semiarid systems adapted to the environmental heterogeneity by traditionally moving their animals around in nomadic systems. This enabled them to reduce livestock mortalities during droughts and thus maintain high stocking rates. The possibilities for mobility are, however, severely restricted in present times either because the communal grazing areas are small and densely populated, or because mobility has been restricted for specific purposes, for example to control diseases. The need for spatial or temporal mobility in variable environments remains an important issue in the sustainable use of resources in arid communal rangelands (33). This continued restriction of livestock results in encroachments into protected areas as recorded in this study.

Increasing human population pressure, encroachment of rangelands by other land use and resultant encroachment into protected areas may have negative implications on the integrity of protected areas in terms of biodiversity conservation (34). These changes lead to the isolation of protected areas as wildlife movement into and out of the wildlife areas is restricted (35), for example, through fencing to minimise livestock encroachment (Figure 6). Traditional rangelands in many developing countries are currently being encroached by cultivation, driving some herders to illegally use protected areas for grazing their cattle (36-38). Since cattle are an exotic species in these ecosystems, they might have an impact on the local wild herbivore communities, notably through competition (39, 40). Moreover, wildlife displacement may result from competition by livestock for pastures (41, 42). Furthermore, such changes have negative implications on wildlife habitats leading to wildlife population declines (43, 44). As for GonarezhouNational Park, it was evident that livestock encroached into the park in the dry season. Livestock grazing within GonarezhouNational Park could be caused by limited pastures in the communities as a result of overgrazing and increasing livestock populations. Furthermore, the livestock encroachment into GonarezhouNational Park could be a result of weak law enforcement associated with livestock grazing (but see Gandiwa et al. (45) for law enforcement and illegal hunting). Elsewhere, in areas adjacent to Serengeti, despite high densities of livestock close to the boundary of the protected areas, domestic stock was rarely illegally present inside the park. This may indicate that livestock

owners considered the chance of detection and likely financial penalties (fines or confiscation of livestock) too high in relation to the benefit gained from illegally acquired forage and the use of watering areas inside the protected area (46).

Figure 6: Wildlife control fence showing some cattle grazing adjacent to northern Gonarezhou National Park, Zimbabwe, October 2012. Photo credit: E. Gandiwa

Livestock ownership and production in the rural, communal areas of southern Africa has multi-ownership, is multi-purpose in character, with both cattle and small-stock providing several goods and services (47, 48). However, grazing areas are mostly communally owned (15). The problem of multiple managers on a rangeland was discussed in the 'tragedy of the commons' (49). The 'tragedy of the commons' reasons that it is more profitable for an individual to overstock the 'commons' (i.e. communal lands) because s/he derives the entire benefit from each additional animal but the cost is shared by all. Due to this phenomenon, a growing number of livestock will populate the rangeland and will eventually exceed its ecological carrying capacity, which will lead to rangeland degradation (49). The theory has, however, been criticised; some argue that communal lands are not completely without management rules, as Hardin implies in his theory. Livestock owners may, to a certain extent, regulate their herd size but cannot always link this to a particular grazing strategy. This is because they are bound to written and unwritten rules that govern the use of the communal rangeland (50).

Our study showed that rainfall did not change significantly between 1969 and 2011 in the northern GonarezhouNational Park ecosystem although the rainfall variation was 40%. It has been reported that when relationships of rainfall with time are not significant, any population density trend could possibly be attributed to changes in the potential carrying capacity of the land, rather than rainfall

induced changes (32). Environmental change in savannas with rates of climatic variability (CV) higher than 30% (corresponding roughly to 300 mm of rainfall or less) was reported not to be driven by stocking rates but by the erratic character of rainfalls. Only in savannas with CV rate lower than 30% (i.e., with average annual precipitation above 300 mm) was livestock density the main force driving environmental change (30). Therefore, it is likely that the perceived rangeland degradation in the communities adjacent to the northern GonarezhouNational Park is being influenced by rainfall variations.

CONCLUSIONS

Our results showed that livestock encroached into Gonarezhou National Park mostly during the dry season and also that local people generally perceived that there was some degradation of rangelands. Moreover, our results showed that rainfall did not change significantly between 1969 and 2011 in the northern GonarezhouNational Park ecosystem although the rainfall variation was high. Our findings show that by investigating local knowledge and perceptions we can provide some insights on livestock grazing and rangeland degradation in semiarid savanna ecosystems.

RECOMMENDATIONS

It is apparent that many protected areas may become degraded by land use and other factors occurring in the unprotected parts of the surrounding ecosystem. Thus, maintaining protected areas often will require some level of conservation-oriented management in the unprotected portion of the ecosystem (51). It has been suggested that destocking rangelands would result in a serious decline in the productivity of pastoral production systems and is not likely to halt rangeland degradation, but that land use policy interventions should focus on the optimal distribution of animal abundance in space and time (52). Policy formulation should, therefore, be based on actual evidence, rather than unsubstantiated notions. However, this is not always possible because of insufficient research in many instances (33), hence, this calls for more research on livestock grazing and rangeland degradation in semiarid savanna ecosystems to enable well-informed policy to be developed. Finally, there is need to enforce the rules and regulations regarding livestock grazing inside protected areas in order to enhance both livestock production and wildlife conservation in semiarid savanna ecosystems.

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DECISION SUPPORT SYSTEMS IN COMMERCIAL AGRICULTURE: Case study on ICT Adoption and Use by Farmers in the Western Cape Wine Industry to assist emerging farmers in decision making.

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ABSTRACT

The wine industry is complex, hence the established and emerging farmers who operate in it are faced with environmental, social and economic constraints. Even though various issues have been pointed out to be contributing to the slow uptake of ICT by emerging farmers (1), (2) however pointed out that DSSs can enhance gains in economic, social and environmental benefits. This paper investigates how wine farmers use ICTs to assist emerging farmers to adopt and use in decision making processes. Literature analysis, interviews as well as observations were used to gather data. The interviewees emphasised the importance of ICTs in their decision making, they mentioned that without the use of ICTs in decision making processes their businesses will crumble. In order to prosper in their business, emerging farmers need to invest in ICTs as useful tool in improving livelihoods of both the farmers and their workers.

Keywords:,**decision making, Decision Support Systems, emerging farmers, wine industry, Agriculture, Information and Communication Technologies**.

INTRODUCTION

In South Africa, new farmers are entering the agricultural sector, these farmers, also called emerging farmers, and are aspiring to establish themselves in the agricultural industry. They are entering a complex environment with little or no knowledge of the complexity of the industry and or environment. The emerging wine farmers have to operate in an environment that is capital intensive with high operating costs, an environment that is complex where they are faced with environmental, social and economic constraints. The prevailing global economic crisis which also resulted in the fluctuation of the Rand (monetary unit), workers' protests and in job losses forced

consumers to spend less, resulting in a lower demand for wine and related products. As a result farmers run a high risk of business failure.

Prior research done in the wine industry in the Western Cape concluded that commercial farmers use Information Communication Technologies (ICTs) for production, marketing and communication (3). (3) outlined that farmers use ICT in production and for marketing their products, both locally and internationally as well as communicating with other stakeholders in the business. However, the results from the research by (4) in the Western Cape wine industry did not clearly spell out the use of decision support tools by the farmers.

One of the ways to mitigate the risk of failure of these emerging farmers is to find quality information through technology in order for them to make quality decisions. Decision making is crucial; it is one of the most important tasks of management in running a successful business (5). Tools to support decision making such as decision support systems (DSSs) help structure the decision processes and support the complicated analysis of resource allocation problems, environmental and socio-economic constraints as well as management objectives. DSS tools can also enhance gains in economic, social and environmental benefits (1). Decision support systems (DSSs) are computer applications along with a human component that can mine through large amounts of data and pick between the many choices. (6) define DSSs as computer based tools developed to provide analysis and advice for decision makers

The use of ICTs to support decision making can assist stakeholders and decision makers to make the best decisions in order to survive and gain maximum profits in the industry. This research explores how the use of ICTs has affected the farmers' decision making and their entire farming business as well as establish if it is capable of continuing impacting them positively in the future.

OBJECTIVES

This study addresses how the ICT infrastructure could support farmers and emerging farmers in decision making. The paper investigates how farmers in the wine industry in the Breede River Valley region of the Western Cape province of South Africa use ICTs to support decision making. The research findings will then be used to assist emerging farmers in the industry to adopt and use the ICTs which can help their decision making and hence improve their entire farming business. In addition, the paper also looks at the broad categories of decisions the farmers make, how they reach a decision in their operations as well as the type of information and technologies the farmers require to support their decision making.

METHODOLOGY

The Breede River Valley region of the Western Cape which is the largest wine producing area in South Africa, was used as a case study. The case study is the most appropriate strategy for this study since it enables us to gain a rich understanding of the context of the research and the processes being enacted (7). Therefore in this research the case study enables us to gain a rich understanding into the use of ICTs by the wine farmers and decision makers in the Breede River Valley in the Western Cape province of South Africa.

Qualitative methods were used in this study due to the exploratory nature of the research (8). The research takes an interpretive approach since qualitative research has an interpretive character, aimed at discovering the meaning events have for the individuals who experience them and the interpretations of those meanings by the researcher [9]. An inductive approach is taken in this study as (8) mentioned that it owes more to interpretivism.

This study took a subjectivist view, social constructionism as the ontological stance which views reality as being socially constructed by the social actors who perceive different situations in varying ways as a consequence of their own view. The different interpretations affect the actions of the social actors and nature of their social interaction with others, seeking to make sense of their environment through interpretation of events and meanings they draw from these events (8).

The assumptions about knowledge and how it can be obtained is referred to as epistemology (10). (11) articulates that it is crucial to know what these assumptions are in qualitative research. Qualitative research can be positivist, interpretive, or critical (Figure 1).

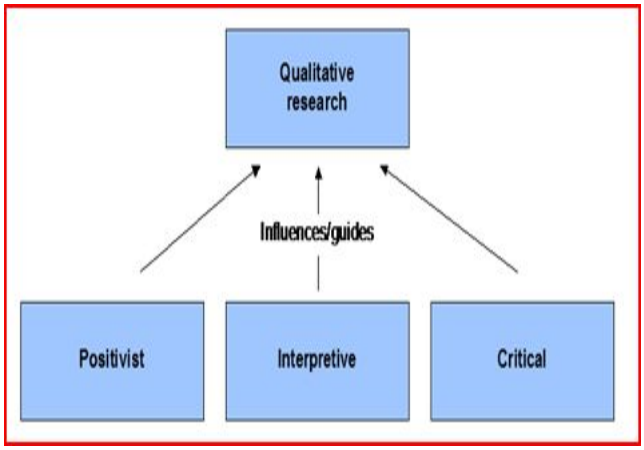

Figure 1: The underlying philosophical functions of qualitative research (11).

This research follows an interpretivist stance which refers to the way we as humans attempt to make sense of the world around us (8). Interpretive research requires that the social scientist must collect facts and data describing not only the purely objective, publicly observable aspects of human behaviour, but also the subjective meaning this behaviour has for the human subjects themselves (12). The studying of how individuals experience and interact with their social world, the meaning it has for them, is considered an interpretive qualitative approach (13).

Literature analysis, in-depth interviews with twenty stakeholders and observations were used to collect data on what types of ICTs farmers use, how they use them to effectively support their decision making as well as suggestions as to what needs to be done to improve the use and uptake of ICTs supporting decision making. The qualitative interview is the most common and one of the most important data gathering tools in qualitative research (14). Interviews were used to gather primary data in this study. Secondary data was obtained through literature analysis also known as document analysis and from sources such as reports, publications, universities, research institutions and also from other stakeholders such as officials from Department of Agriculture (DoA) and agriculture policy makers. Established farmers, emerging farmers, consultants and vendors were interviewed to enable collection of information on the use of ICTs or decision making in the industry.

Well established farmers, most of which started as emerging farmers provided useful information as to how they have and still adopt latest technology which aids their decision making. Vendors who provide the technology and agricultural products to farmers, also provided insight on how their customers use ICTs in decision making and the trends in relation to that. Consultants from the government such as viticulturists and private consultants encompassing viticulturalists, BEE consultants as well as GPS specialities who work with the farmers were also interviewed.

Gathered data in this study was summarised, categorised, developed into themes and then findings were derived. Conversation analysis and hermeneutics were used to analyse data in this paper. The authors of this paper although they followed an inductive approach, do not claim or even suggest that the findings are applicable to all farmers and emerging farmers in the wine industry. The findings only suggest and propose possible ICT short comings and solutions for this complex problem.

RESULTS

All the interviewees agreed that decision making is an important aspect of the farming business. This is augmented by the fact that decisions taken today have a long term effect on their business. Farmers make decisions on a daily, weekly or monthly basis as well as strategic decisions. The

decisions farmers make involve, profitability assessment, labour management (recruitment decisions, when to hire seasonal workers, what skills are needed), budgeting and financial planning. Farmers also make planting decisions (that is what to plant, where, in what quantities and when), marketing (need to establish if their product will sell, what's on demand in the market) as well as vineyards protection and management (spraying, fertiliser application and irrigation).

In order to reach a decision in their business most farmers mentioned that they consider market trends to ascertain what is on demand in the market. This helps them grow cultivars and varieties which they will be able to sell. Unlike other agricultural products like grains, grapes are more perishable, hence the need to get the market first in order to avoid massive losses. Some of them articulated that they look at profitability and all their farm decision will be centred on that. Knowledge of their farm terroir emerged as an important aspect when farmers responded to the question, 'how do you reach a decision'. This will enable farmers to make informed planting decisions as terroir is crucial in that aspect. There were some other farmers who revealed that their decision making is centred on quality. They value quality in their business such that a quality product is all they think of when they make decisions. Consultants and colleagues' input was also cited as of significance when reaching a decision in farm operations. Their experience and knowledge could not be ignored if one has to make informed farm decisions.

The interviewed farmers use different ICTs to support decision making in their business. Computers, cell phones, landline phones, internet, fax, email, television, printers, GPS, satellite mapping, moist detection systems for irrigation, computerised irrigation, farm specific software, general software and scanners are generally used. It was discovered that the most common types of ICTs farmers use, are cell phones as the most convenient and significant one due to its portability and ability to perform several other functions apart from calling and receiving calls, although connectivity is mentioned as a frustrating and ongoing challenge, and computers. Computers are used to connect to the internet, sending email, pictures and text messages. When asked what type of ICTs they require to support their decision making, the majority of the farmers indicated that it cannot be one ICT but a combination of the above mentioned ICTs. Moist detection, irrigation, spraying, fertilising and financial planning and execution for example are done by computers. In addition some can use their cell phones to connect to the internet on their computer.

The model

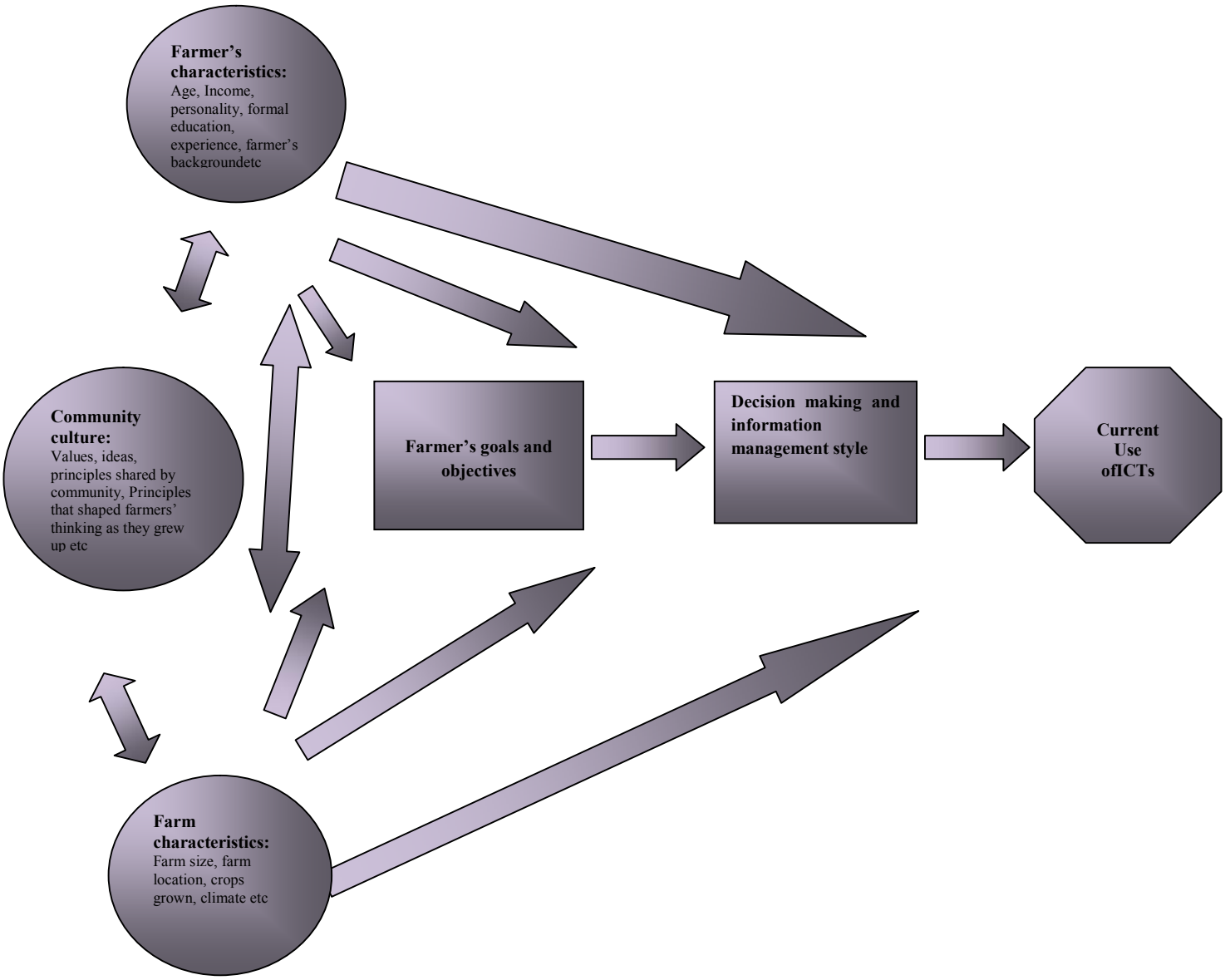

Figure 2: Extended information innovation adoption model (Adopted from (15)).

It is assumed, from the model (Figure 2) that there are direct relationships between antecedent variable, (circles is an underlying cause for a situation or scenario such as permanent characteristics of a farmer) and outcome variables (octagon which is the single variable reflecting the use of an on-farm computerised information system). The model shows reversible arrows on antecedent variables, which indicates a two-

way relationship between the variables. Both ways, a variable may affect the other positively or negatively for example income as an independent variable maybe interacting with other some farm characteristics and/or some elements of the community culture.

Mediating variables (rectangles) are variables describing rather than when effects will occur by accounting for relationships between independent and dependent variables. They are indicated by one-way arrows.

The mediating variables explain the relationship between outcome variables and antecedent variables with each antecedent variable affecting the mediating variables either negatively or positively. For example, a farmer's income might affect the farmer's goals and objectives, the style of management and the ultimate use of ICT. The dependent final outcome variable is influenced by all the antecedent and mediating variables (4, 15).

This study investigates the use of ICTs by farmers in their decision making hence all the three types of variables were looked at in this study. The authors (4) wanted to determine relationship between certain variables and their adoption of computer systems. The variables included farmer's age, formal education, and personality, operational skills, farming culture, farm characteristics, advisory services on agricultural practices, information management skills and economic benefits perceptions. They found significant relationships to exist between farm size, farmer's age, goals, information management practise and learning style and the farmer's adoption of computerised systems (4, 15).

Since this study investigated how the farmers use ICTs to support their decision making, relationships between variables were explored to determine which variables affect the ultimate use of ICTs by farmers. Most of the variables mentioned by (15) applies to this study for example farmer's income and education level affects the farmer's use of ICTs as well as what kind of culture they grew or live in. Farm characteristics such as size, crops grown, location and climate also affect the farmer's use of ICTs. The antecedent variables shown in the model (Figure 2) are the variables affecting the farmers' goals and objectives for example the farm characteristic such as climate or location affect the farmers goal and objectives for example if there will be a change in climate in that area, the farmer will have to invest more on measures to combat that or avoid varieties likely to be affected by the change in climate. In the same way, farmer's characteristics such as age or income also affect their goals and objectives. An aging farmers might not be fit enough to manage the vineyards hence the need to reduce the hecterage or hire a manager. If the farmers' income is low then he has to plant vineyards manageable with the low income

The mediating variables together with antecedent variables as seen on Figure 1 affect the farmer's management style and their decision making. It affects their choice of decision support systems (DSSs) and the ICTs they use in decision making. All the variables, both antecedent and depending variables affect the use of ICTs for decision making as the diagram above illustrates. In the Breede River Valley region of the Western Cape, South Africa; where the research is focused, farmer

characteristic which are also affected by the community culture greatly affect the farmers management style and their adoption and use of DSSs.

Information on viability of the business is important in the farmers' decision making process. Farm specific DSSs such as FarmMS and general accounting software such as Pastel or Microsoft Excel is used in such context. FarmMS calculates farmer's expense per hectare or per vineyard which helps him make a better informed decision on profitability. The general software can be used to produce financial statements which the farmer can interpret and ascertain his profitability.Established farmers and emerging farmers need an environment where they have stable connectivity through broadband access, mobile connectivity, continuous training in ICT for all involved, fee availability to useful agricultural data bases, subsidies for ICT infrastructure and a good support backup system.

Table 1: The technologies used by the interviewees

Which technologies are suitable to support your decision making?	**Responses**
Cell phones	100%
Computers	100%
Internet	100%
Integrated computerised systems	50%
GPS and GIS	33%
Email	100%
Software packages	67%
Computerised irrigation	67%
Pesticide application programs	67%
Television	33%
Land line phones	100%

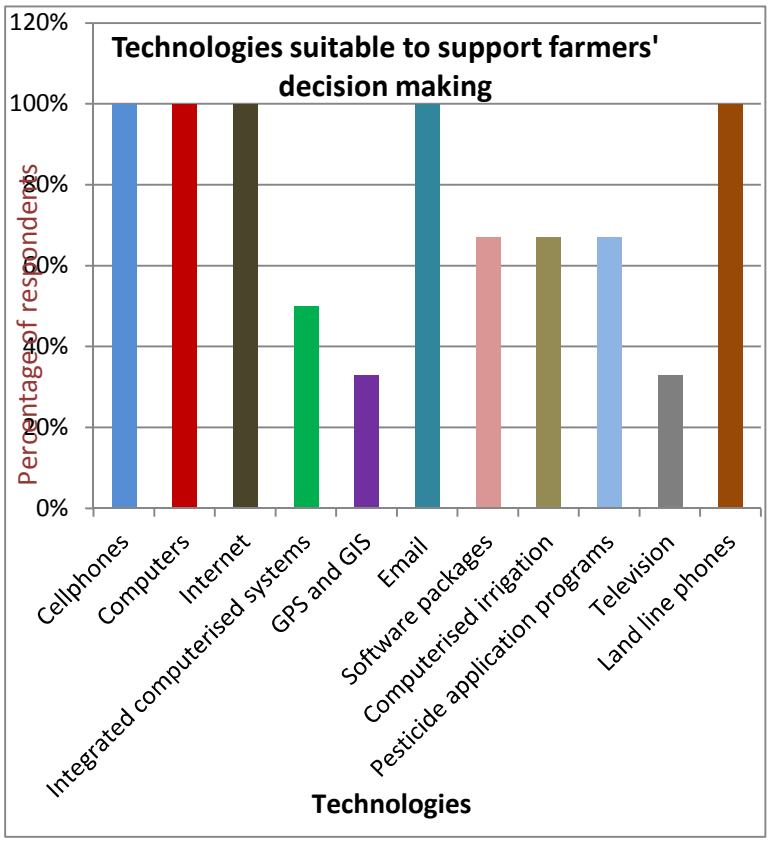

Figure 3. Graphical representation of the technologies suitable to support farmers in decision making

Table 2.Themes and findings

Theme	**Findings**
Agricultural domain knowledge	Terroir knowledge is used in the decision making process Scientific soil analysis is used for soil preparation, planting and fertilisation decisions.
Family	Farmers' spouses or children use the software to create information for the farmer to use in making decisions.
Finance	Financial decisions are based on information gained from different sources including banks and accountants. Book and recordkeeping is used as a tool for decision making on all aspects of farming. On demand financial information is needed for farmers to make decisions.

ICT	ICT is widely used by the farmers Computers and software such as the Microsoft suite is used by farmers Internet services are gaining ground as a supporting tool for decision making by the farmer There is a lack of integrated systems in use on the farms GPS and GIS technology is under utilised by farmers in their decision making processes Emails are used by farmers and reduces the decision making time cycle Computerised system creates useful information for decision making Application programmes are useful in the decision making processes Landlines are old technology but still in use because of the poor net work coverage of mobile service providers
Information resources	Farmers make use of information from a variety of sources including consultants, vendors; own experience, neighbours experience, websites, journals, magazines and many more, on many aspects of the farming enterprise. Farmers use several sources of information such as industry information on market trends to make long term decisions To make decisions farmers make use of consultants and neighbours with experience and knowledge of the area Farmers use experience of neighbours and consultants when making decisions Farmers use the history of the farming operation's to assist in the decision process Farmers need information on weather data, advice from consultants, information on market trends and analysis, financial information, workers' opinion, advice from experienced fellow neighbouring farmers, information on the scientific assessment of soil, information on industry statistics and performance as well as technical information Weather information is one of the highest priorities for farmers in order to make decisions Industry information is used for strategic and tactical decisions Consultants are widely used by farmers when making decisions Experienced neighbours are often consulted and used by farmers when making decisions Television weather reports are not very useful technology tool for information

	gathering by farmers as compared to website which are more precise and area specific Farmers consult farm workers in their decision making process
Labour	The involvement of farm workers when acquiring new employees are important
Marketing	Market trend information is used for strategic decisions
Mobility	Internet and mobile banking is important tools for farmers. Cell phones are generally used by farmers but coverage and connectivity is a problem and causes inefficacies in the decision making process
Quality information	Farmers need quality information to make marketing decisions for local as well as international markets Quality produce is important in the decision making process
	Farmers need reliable, accurate and timeously information from ICT to improve the quality of their decision making
Risk management	Risk assessment is done before making decisions
Strategy	Farmers know the importance of strategic, tactical and operational decisions to be a successful farmer Reduces the time of decision making by farmers

CONCLUSIONS

ICT has been generally adopted by wine farmers in the Breede River, of the Western Cape. From the data collected by means of interviews and observations it was clear that the adoption rate and use of ICT differed between the farmers as well as emerging farmers. The adoption and use of ICT were closely related to the infrastructure available to the farmers, the educational level and exposure to ICT of the farmer, and the diversity of the farming operations.

All the interviewees used mobile technology to communicate (if reception is available) and all of them used computers for banking and weather reports. This kind of approach is not new, as banking was and still is the gateway for many people to do e-Commerce for the first time. The farmers also used the internet to gain insight in market trend and international producer prices.

The respondents expressed a lack in technical skills and the need for training in ICT. Training that is directed to the specific needs of farmers and has sustainable frequency is needed. As a follow up to this study, an e-learning system on how farmers can learn on their own how to use the ICTs can be developed as well as a model for use and adoption of ICTs to support decision making in the industry.

From the interviewees done with the stakeholders it became evident that many of the farmers are still afraid and sceptical of the importance of ICT in the business. Despite the fear and scepticism, the interviewees all agreed that ICT will become more and more important in the future.

Some of the farmers, especially those with a focus on export, depend heavily on ICT such as the internet and mobile connectivity. Their scepticism comes from the frustrations they are experiencing with the poor stability of the infrastructure available to them. The down time they experience at critical moments in the business processes leads to missed opportunities and incorrect decision making. The fear factor or factors lies within the fast changing ICT environment. The fast pace of change in technology, for example new mobile models doing more, lets the farmer feel inadequate and before admitting to such inadequacy the farmer will rather stay with what he knows best.

For emerging farmers, still finding their way, the use and adoption of ICT is very low on their priority list although they admit that it is very important for their sustainability. It is therefore suggested that emerging farmers with the same needs as well established farmers', partner with the established farers so that they can grow and get accustomed to the ICT agricultural ecosystem.
Farmers mentioned that they value practical expertise and knowledge possessed by consultants and their colleagues in the industry. For emerging farmers this is important and they need to build relationships with the established farmers as all of the established farmers expressed their willingness to be of assistance where ever they can.

Government, private institutions, researchers and academic institutions can help the emerging farmers with training and show them how best they can adopt and use ICTs to support their decision making and consequently improve their business. Showing or explaining the benefits of using ICTs for decision making to the farmers is also necessary and very important in making them understand and appreciate more the role technologies play in their business since some of them think all technologies are more expensive and overrated.

It is recommended that a model for ICT use and adoption to support decision making for the agricultural sector must be developed; this model will in turn benefit the whole agricultural sector and not exclusively the wine industry. Opportunities for interaction between government, private companies, academic institutions and researchers need to be explored. Workable and practical policies, partnerships and structures must be put in place that will benefit the wine industry but also the South African Agricultural economy as a whole.

RECOMMENDATIONS

Co-decision making is when farmers consult their employees in certain decisions where their input is much valued. Ignoring workers' opinion in decision making might adversely affect the farmers' business.

Market trend analysis and constant information update from buyers and wine makers are a great source of information which no farmer should ignore.

Importance of experience -even though two-thirds of the farmers interviewed rely on their accumulated experience when making decisions, none mentioned that they solely rely on it in their decision making contrary to a number of literatures.
All the farmers, consultants and vendors interviewed agreed that the use of mobile devices is crucial in supporting farmers in decision making. There is therefore need to keep encouraging farmers to effectively use their mobiles in assisting their decision making.

Internet has a lot of benefits such as access to important information on weather, markets etc, it also provides better and effective communication with stakeholders through emails or Voice over Internet (VoIP) such as Skype or Google video chat.

Use of videos can be a very good way to train farmers on such technologies. Vendors and consultants in collaboration with academic institutions and private organisations can produce videos which can be shared on emails to farmers or on social network sites. Farmers will need to be trained on how best they can download videos on emails or how to play videos from social network sites such as Facebook, Youtube, Twitter etc.

Funded by Department of Agriculture, Western Cape supported by the Department of Agriculture, Forestry and Fisheries as well as other institutions; www.fruilook.co.za the successor of www.grapelook.co.za was launched in January 2012. It is a very useful web tool which is capable

of positively transforming the farmer's decision making and his business as a whole. Farmers can sign up for free to enjoy the service. It uses satellite imaging to provide 9 parameters to monitor the farmer's vineyard.

Subsidies - the majority of the farmers believe that government's support by way of subsidies can help improve their use of ICTs in their business to support decision making. They pointed out to the higher costs of technology as a hindrance to effective use of these decision support tools.

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The Commercialization of E10 Fuel In Zimbabwe: Impediments, Perceptions, Realities And The Way Forward

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Abstract

Close to two years on, the market acceptance and uptake of Zimbabwe's ethanol-blended petrol (E10) remained in pessimism, yet elsewhere in the world, the same blend has packaged as a *'premium, super brand'*. This study thus explores the perceptions and realities surrounding the commercialization of 'green fuel' in Zimbabwe. We use a multiple methods approach to generate richer data, and deeper insights about the commercialisation of E10 fuel in Zimbabwe. The study uncovers a host of commercialization challenges, conceptions and misconceptions ranging from technical issues concerning the fuel's composition, engine compatibility, mixed pricing perceptions as well as policy-related issues. Revealing how E10 fuel has been a success story in other countries, our study shows how marketing education can be used to create awareness of the economic benefits for consuming E10 fuel. Our findings contribute to an understanding of how consumer misconceptions about a product or service can affect product image and sales. We conclude that consumer education is needed about the E10 fuel project, as it has the potential for creating jobs, improving the supply of fuel in Zimbabwe, while promoting a green environment.

Key Words: ethanol-blended petrol, mixed pricing, engine compartibility, bio-fuel.

INTRODUCTION

Historical Background

The dawn of Zimbabwe's independence saw the government dedicating substantial resources towards the establishment and capacity building of centres for innovation. This saw the development and advocacy of the use of bio fuels, which only failed during the national drought of 1992. "For more than a decade, during the 1980s, all petrol sold in Zimbabwe was a petrol-ethanol

blend, with the ethanol percentage sometimes reaching 20 percent. No one minded. All cars worked as designed..." [1]In 2011, more than 20 years post-independence, the government resurrected the bio fuel sector, a move that was targeted at increasing energy independence, creating jobs in rural areas and combating climate change. All things being equal, up to 20 percent of Zimbabwe's fuel imports were to be replaced by biodiesel and ethanol (from sugarcane). As a result, about US$600 million was invested into the mammoth ethanol project at Chisumbanje in the Manicaland Province of Zimbabwe. The producer, Green Fuel Ltd; a foreign private investor, maintains that they have a transparent *Build Own, Operate and Transfer arrangement* with Agriculture Rural Development Authority (ARDA) under which the two private investors involved will develop the project, run it to recoup their investment before handing it over to the State. As such, the project has been awarded a National Project Status by the Zimbabwean Government. [2]

E10 has however come with a host of commercialization challenges on the market, ranging from technical issues concerning the fuel's composition (10:90 of ethanol and petrol respectively), mixed pricing perceptions as well as issues of blame game from both the Government and Fuel Distribution Companies. Given the increasing need for evidence-based policy making, there is need for research that will help policy makers, fuel distribution companies, and consumers to understand the true nature of E10 fuel. It is against this background that the researchers undertook to investigate the determinant factors that are hindering the successful commercializing of E10 fuel.

Global Trends in Blended Fuel Consumption

Research reveals that there are several developed economies that have adopted more of ethanol-blended fuels than unblended fuels. However, not all countries have adopted 10% ethanol. For example, Brazil has adopted even up to 20% in some of its applications. Rising oil prices and apprehension about global warming have prompted governments to rethink their energy supply policies. [3] Such countries include

U.S.A., China, Australia, India and Brazil (the world's top producer), amongmany others. Within this, there is an interest in Brazil's applications. For example, Japan's interest in Brazil's ethanol was prompted in 2004 when Prime Minister JunichiroKoizumi visited an ethanol production facility in Brazil and said his country was interested in the alternative fuel as a means of meeting the demands of the global environmental agreement signed under the Kyoto Protocol. The Brazil-Japan ethanol relationship has grown significantly since then, with the announcement in 2005 of the formation of the Brazil-Japan Ethanol Company, a partnership between Petrobras and Japan's Nippon Alcohol Hanbai. Coincidentally, Japan serves as the major source of Zimbabwe's second hand cars.

While Japan has successfully advocated for the use of ethanol, the Zimbabwean market seems resistant. In fact, Japan has since adopted ethanol-blended fuel since 2005. Therefore, this study seeks to understand why there is consumer resistance to the E10 fuel in the Zimbabwean market. Equally important is to understand whether there are lessons that Zimbabwe can learn from developed economies such as Japan, and how this can help to improve the adoption of ethanol blended fuel.

The Status of Ethanol fuels in Zimbabwe

Despite the enormous scarce resources invested into the ethanol project, the market uptake has remained very low. Few Zimbabwean motorists and Fuel Distributors appear interested in the E10 fuel. Those driving into service stations frequently find a queue at the unblended petrol pump while the E10 (Blend) pump is occasionally unattended. This means Zimbabwe is still depending on the expensive imported fuel regardless of huge stocks of a locally produced fuel. The company producing ethanol for the blended petrol, Green-Fuel Ltd, has since suspended production as it ran out of storage space after it reached the full stock of about 10 million litres. As a result, the company has retrenched about six hundred employees [4] after the two year old plant was shut down.

METHODOLOGY

The study was approached from an exploratory perspective since the researchers intended to establish the realities surrounding E10 commercialisation, [5] that is, what is really causing E10's failure in the Zimbabwean market. This helped in clarifying the researchers' understanding of the research problem. [5] The research paradigm was integrated, hence, the researchers took the multiple-method research strategy to achieve the study's objectives, though data collection and analyses were primarily qualitative.

Data for this study were gathered in four phases, and using multiple methods. Multiple methods are increasingly being recognised for their ability to bring multiple points of view to a research project, taking advantage of the strengths of each of the qualitative components to explain or resolve complex phenomena or results.[29]The first phase involved an appreciation of the *status quo.* This was achieved through a non-systematic review of different forms of publications including newspapers, relevant websites tracking and participatory observations. The researchers followed through the E10 news from the time the product was rolled out for commercialisation, its acceptance by distributors and final uptake by the market. Some participatory observations were made by randomly driving in to some service stations in and out of Harare where the fuel is and/or

is not being distributed. The main intention of this was to obtain first-hand information about everyday consumer experiences.

The second phase involved holding 32 key informant interviews with conveniently sampled service stations' staff (i.e. fuel attendants and station managers / supervisors). The interviewees were conveniently selected from service stations that distribute, and those that do not distribute E10 fuel. During this phase, short, but structured interceptive mall interviews were held with 150 motorists randomly intercepted at these service stations. To participate in this research, respondents had to be aware of, or have been engaged in the usage of E10 fuel. The interceptive interview guide was divided into three sections: the first section dealt with motorist evaluations based on their experience with E10 (if any); the second section asked the respondents to rank the attributes (in the first section) in order of expectation / preference (regardless of past experiences), while the third section was concerned with their perceptions of E10 fuel and what they thought could be done to improve the situation. The third phase involved a key informant telephonic interview with one of Green Fuel Ltd. Management staff who preferred anonymity for the purposes of success of this research. The real issues facing the company and possible challenges were scrutinised. It is also during the interview that the research problem was confirmed, while technical issues involved in E10 fuel were clarified.

During the fourth and last phase, the researchers reviewed some success stories of E10 uptake in other countries. This involved an examination of publications on how those countries have managed to gain Ethanol fuel acceptance in their respective countries. The researchers reviewed cases from Japan (the major suppliers of used cars to Zimbabwe), U.S.A, Brazil and China – who are on the lead regarding the adoption of blended fuels, some even using up to E85 [6]. The information gathered from the reviews, together with data collected from phases 1 and 2, were used to establish a way forward (roadmap) for the Zimbabwe's situation.

Table 1 justifies the multiple-stages in gathering data for this study.

Table 1: Justification of Multiple Data Collection Techniques

OBJECTIVE	MULTIPLE DATA SOURCES
To understand the nature of the research problem i.e. E10 commercialization challenges	Published Material Participatory observations
to create an in-depth and rich account of E10 uptake and issues arising	Key informant interviews with fuel Distribution (service stations') staff (32)
To confirm the research problem and gain technical insights of E10	Key informant (telephonic) interview with Green Fuel Ltd. (1)
To appreciate customer perceptions on E10 fuel vis-à-vis their expectations.	Short interceptive mall (service station) interviews (150)
To explore the possible way forward.	Success stories Reviews A combination of all methods above

During data collection, respondents were not forced to partake in the study. Instead, the researchers had to first clarify the need for the research and how the study would impact the future of the country. Consent was thus obtained from the respondents before their participation in the study.

RESULTS AND DISCUSSION

Distribution of E10 fuel

The study found out that E10 is distributed mainly in about 30% of service stations in Harare, a few in Bulawayo and Mutare, and on 1 Service station each in Chegutu, Rusape (Shell), Marondera (Sakunda Fuels) and Gweru. It was also found that the first distribution point of E10 fuel in Zimbabwe (as at November 2012) was in Mutare, which is about 200km from the plant, a clear indication that the product has not been sufficiently marketed and / or has not been accepted within its immediate locality, possibly due to unstable socio-economic relations between the firm and the community. [7] Our results reveal that E10's overall market coverage in Zimbabwe stands at +/-17% (as at Oct / Nov. 2012). Insights from the exploratory phase revealed that there are no E10 supplies to Harare satellites, ChinhoyiKaroi, Kariba, Plumtree, Beatrice to Beitbridge as well as Murewa to Nyamapanda, a clear indication that distribution of the two year old product is still at grassroots level.

Asked why they do not distribute E10, 83% of the service stations who participated in the study indicated that though they would love to, they learnt from the current distributors of the product that E10 does not sell quickly;hence a slow sales turnover. 76% of the service stations indicated the~~ir~~ need for a third E10 fuel pump since they only have two pumps for unblended petrol and diesel only; while 14% were of the view that since it is not mandatory, they have every right to distribute what they felt is marketable. 10% of the respondents raised their reservations on E10 price, which they felt was too high to attract customers. As at November 2012, the E10 price ranged between $1, 43 and $1.49 / litre versus $1.45 - $1.52 / litre (for unblended petrol) depending on location.

90% of the service stations distributing E10 indicated that they do so because they felt that the product isenvironmentally friendly. Another reason cited was that the product is 100% Zimbabwean, and as such, it needed their support. Providing consumers with a set of choices was also a reason for stocking and distributing E10. About 60% of these service stations expressed their satisfaction with E10 sales. These were located in low-densities especially in Harare (Avondale, Belgravia, Borrowdaleetc). 40% of the service stations selling E10 fuel indicated that they were not impressed with E10 sales. For instance, one service station in Harare City centre indicated that they sell a daily average of about 20 litres of E10 fuel, compared to an average of +/-500 litres of unblended petrol. These findings were consistent with insights that emerged from our participatory observations.

The major differences in pricing and sales were noted especially between city centres, high and low density areas.

Consumer Perceptions

The study was also aimed at understanding consumer perceptions about E10 fuel. Of the 150 respondents, 113 (75%) identified themselves with at least some level of awareness of E10 fuel while 37 (25%) were not aware of the product. Interestingly, these 25% were mostly from outside Harare. Of the 113 who were aware of E10, 31% have used and / or are using E10 while 69% have never tried using E10. Asked why they have not used E10, 99% of the motorists indicated that they have *"heard"* that E10 "*destroys engines*" and also *"gets used up quickly"*. Further asked if they have proven these claims, none of the motorists have proven anything, a clear indication that market education is needed. On our observations, we noted that some flyers advertising E10 were at very few service stations. It was also observed that these were in service stations located in low density areas at the expense of service stations located in medium density and high density areas where sales are still problematic.

We also found that some companies, as users of E10, have revised their company policies to stop their drivers from fuelling and / or re-fuelling company vehicles with E10. We interpret this indication of how the misconceptions about E10 fuel in Zimbabwe have filtered across different types of user groups, including individual consumers, and different organisations.

Of the 31% who have used and / or are still using E10, 95% expressed their satisfaction with E10 performance and indicated that they would recommend others to use the product; In fact, the study established that about 60% of these E10 advocates are products of positive word-of-mouth. The E10 advocates had the following "top three" reasons to adopt E10:

- ✓ E10 cleans your engine, tank and carburettor
- ✓ "I can alternate E10 blend with Unblended petrol anytime"
- ✓ The whole world is going "green", why not rally behind?

Reservations were however raised in terms of E10 price. The E10 advocates felt the product is relatively expensive. When reminded that Ethanol was only 10% while 90% is still imported cost, the E10 advocates were of the view that the country should move to higher ethanol blends (E15, E20, E25...up to E85) as long as that will lead to "lower price" and also as long as that will reduce the nation's dependency on imported fuel. Following from this, 53% of E10 advocates expressed their loyalty with the ethanol blend such that they indicated that they would not have any other fuel in their vehicles as long as E10 is still available elsewhere. However, in the event of fuel shortages, 100% of the motorists who participated in this study disclosed that they would go for E10 fuel, at any price, if there is to be no alternative.

The analysis was followed by identifying the expectations of potential customers of E10 fuel, to "guarantee" its successful commercialization. These are those factors that motorists perceived they could consider in making an initial purchase of E10, and they included pricing, safety, compatibility, uniqueness, 'switch*ability'*, communication / assurance, availability and market support, as illustrated in table 2. Using a five point likert scale, respondents were asked to either agree or disagree with a set of evaluative statements where SA = strongly agree; A = agree; NS = not sure (neither agree nor disagree); D = disagree; SD = strongly disagree.

Table 2: Motorists' Perceptions on E10 Fuel

	E10 Characteristics						
Response	Uniqueness / Originality	Compatibility / Quality	Communi cation/ Assurance	Safety &enviro-friendliness	Availability	Relative Price	Market Support
SA	0.49	0.50	0.09	0.10	0.11	0.05	0.07
A	0.29	0.18	0,05	0.40	0.07	0.06	0.11
NS	0.12	0.05	0.17	0.15	0.14	0.20	0.10
D	0.04	0.17	0.49	0.08	0.41	0.52	0.42
SD	0.06	0.10	0.20	0.27	0.27	0.29	0.30
Total	100	100	100	100	100	100	100

For the purposes of this research (labelling), uniqueness relates to an innovation or product of its own kind. While an innovation could be unique, that may not guarantee its quality i.e. durability and fitness for intended purpose. [8] Communication is taken to relate to the degree to which the E10 is promoted and awareness programmes. Availability relates to the respondents' rating on their **access to E10 fuel.** Relative price refers to the consumer perceptions with regard~~s~~ to E10 market price in comparison with unblended petrol, while market support relates to post-E10 launch activities such as reminder promotions, customer service – back-up, follow-up, guarantees and warrantees. [9]

While 73% of the respondents associated with E10 confirmed that the product is unique and of quality, it is disheartening to realize that nothing much has been done to communicate and / or promote and fully educate the market of E10 and its usefulness. This has been evidenced by higher aggregates of respondents who disagreed with regards to communication (79%), availability (68%), and market support (72%). The majority (81%) of the respondents perceive E10 pricing as unjustifiably too high for an indigenous innovation …all this has doomed the successful commercialization and subsequent market uptake of E10 in the country, though with vast potential.

Success Stories of E10

The researchers went on to review blended fuel characterization and international standards, followed by a review of the success stories of the blend worldwide. These reviews were meant to deduce some lessons that could be applied in improving E10 fuel marketization and usage in Zimbabwe.

Ethanol Fuel Characterization and International Standards

Ethanol intended for fuel use has to meet certain standards. In the USA, fuel ethanol must be anhydrous (less than 1 percent water). It must also be denatured (i.e. is made unfit for human consumption), usually prior to transport from the ethanol production facility, by adding 2 to 5 volume percent petroleum, typically pentanes plus or conventional motor gasoline. In many countries, ethanol fuel is used principally used for blending in low concentrations with motor gasoline (petrol) as an oxygenate or octane enhancer. In high concentrations, it is used to fuel alternative-fuel vehicles specially designed for its use. [10] On the other hand, Green Fuel Ltd's E10 is indeed anhydrous, meaning that moisture content is removed to achieve a 99,6% fuel grade ethanol that meets international standards [11]. This provides an opportunity for Zimbabwe's E10 to be available for local consumption, and also for export, thus an assurance Zimbabwe's E10 is an internationally standardized product.

Worldwide Ethanol Usage and Rankings

Blends of E10 or less were used in more than twenty countries around the world by 2011, led by the United States, where almost all retail gasoline sold in 2010 was blended with 10% of ethanol. Blends from E20 to E25 have been used in Brazil since the late 1970s. E85 has been commonly used in the U.S. and Europe for flexible-fuel vehicles. Hydrous ethanol or E100 is used in Brazilian neat ethanol vehicles. [12] Thus the U.S. and Brazil account for the majority of bio fuels operating capacity in the world, [13] together accounting for 87.1% of world production of 22.36 billion US gallons (84.6 billion liters).[14] The usage of ethanol fuel has grown over the years because of its environmental friendliness; reduction in overreliance on oil producing companies, and fuel imports; advancement of local technologies and knowledge base; and improved ethanol fuel technologies. [15] The top 10 ethanol fuel producers are shown in table 3.

Table 3: Top 10 World Ethanol Fuel Producers[16]

Rank	Country	'000 Barrels per Day
1	U.S.A.	867.44
2	Brazil	486.01
3	China	37.00
4	Canada	24.00
5	France	18.00
6	Germany	13.00
7	Thailand	7.50
8	Australia	6.50
9	Colombia	4.80
10	Sweden	3.50

In world rankings, Zimbabwe occupies position 38 in the top 40 world rankings [17] while the 4th position is occupied in Africa, of the only four African countries internationally recognized in terms of ethanol production.

Table 4: Ethanol Production rankings in Africa [16]

Rank	Country	'000 Barrels per Day
1	Sudan	0.50
2	Malawi	0.20
3	Ethiopia	0.10
4	Zimbabwe*	0.02

**Given the nature of the research problem, it could still be argued that Zimbabwe has the potential to lead in the African realm given that production has since stopped due to market uptake problems.*

Key Success Factors for Ethanol fuel Adopters

Strong incentives, coupled with other industry development initiatives, are giving rise to fledgling ethanol industries in countries such as Germany, China, Thailand, Spain, France, Sweden, Canada, India, Australia, and a couple of Central American countries.[16] Over and above this, the following have been some of the secrets in the success stories of the top-ranked ethanol producers and users:

- ✓ Capital cost support
- ✓ Direct Price Support
- ✓ Income enhancing subsidies – for example income tax concessions
- ✓ Guaranteed (captive) markets – for instance all government departments become captive market for E10
- ✓ Price guarantees
- ✓ Feedstock price support

Zimbabwe's Import Car Sources vis-à-vis E10 Usage

China and Japan are undoubtedly Zimbabwe's major sources of new and used car imports respectively. Ex-Japanese vehicles have flooded the Zimbabwean roads and market since dollarization of the economy, such that the general price level of cars has taken a downward trend. Apparently, China is ranked World's 3rd in ethanol production [16], a clear indication that the self-contained country is advanced in ethanol advocacy.

Japan is successfully advocating for the use of Ethanol, and it has forged successful strategic alliances with Brazil, the world ethanol leaders, to supply the much needed product into the Japan's fuel pipelines. As noted earlier on, the Brazil-Japan ethanol relationship has grown significantly since the formation in 2005 of the Brazil-Japan Ethanol Company; a partnership between Petrobras and Japan's Nippon Alcohol Hanbai. In June 2012, Japan's local media reported that the Niigata Prefecture (Japan) pioneered the sales of a mixture of gasoline and bioethanol made from rice for animal feed. [18] During the same month, Japan Airlines found and proved that biofuel is more efficient than Petro-Fuel in a Test Flight, a move that has seen the airline joining a steadily expanding number of airlines trying to green their fuel usage. [19]

Mandatory Blending of Ethanol: The Worldwide Perspective

Due to the huge role played by ethanol in enhancing economic development of any country that handles the project(s) well, some top ranked ethanol-producing (and even non-ethanol-producing) countries have mandatory blending policies that support the many benefits of ethanol. Zimbabwe's neighbouring, South Africa can be referred to as the latest case to introduce 'Regulations regarding the mandatory blending of Bio fuels with Petrol and Diesel', documented August 23, 2012. [20]

- ✓ In India, mandatory blending started in 2003, though country-wide blending surfaced in 2004 [21] : what can be picked from this experience is that if Mandatory blending is to be introduced in Zimbabwe, already with mixed feelings – mostly political [22], some preliminary resistance is likely to occur, but acceptance may eventually follow.

- ✓ Since 1976 the Brazilian government has made it mandatory to blend ethanol with gasoline, and since 2007 the legal blend is around 25% ethanol and 75% gasoline (E25).
- ✓ Mandatory blending in Thailand was supported by tax reductions and investment subsidies. This has seen Thailand being ranked in the top ten world ethanol producers, pumping out about 75 000 barrels per day. [16]
- ✓ China has mandatory blending in some regions that had some preliminary distribution and uptake challenges.
- ✓ Just like Thailand, Australia's mandatory blending was supported by tax exemptions and direct support.
- ✓ Japan's Environment Ministry intends to fight global warming and surging oil prices by requiring that all vehicles on the road be able to run on an environment-friendly mix of ethanol and regular gasoline by 2030. The new policy was hailed by leading automakers; General Motors Corp., Ford Motor Co. and DaimlerChrysler AG's Chrysler Group, who have, up to date, produced 5 million flexible fuel vehicles that can run on 85 percent ethanol. In line with this policy, all vehicles produced by Toyota Motor Co., the world's Number 2 automaker, already meet the 10-percent standard. [23]
- ✓ Back in Africa, Kenya has an E10 mandate in place in Kisumu, the country's third largest city. Malawi has also has an E10 ethanol mandate in place, but is dependent on availability. [24]
- ✓ Jamaica has an E10 ethanol mandate that took effect in 2011. [24]

CONCLUSIONS

As can be noted from the reviews done, world ethanol production will continue to grow at an increasing rate. The fact that Zimbabwe is counted in the world rankings implies that the country has a great potential. Results from the study show that there is a gap on market education on E10. This was evidenced by 99% of the motorists, who were aware of E10, but indicated that, they "*heard that E10...*" This implies that wrong information is circulating in the market. This it can be concluded that the majority of E10's 'would-be-buyers' hold wrong perceptions about the performance of the product.

The study found out that 81% of the respondents perceive E10 pricing as unjustified and too high for an indigenous innovation. These included both users and non-users of the product. This has caused much resistance by the market as motorists prefer the 'expensive' unblended petrol than E10, a local product, but *"is only 3 – 5 cents cheaper"*. Thus it can be concluded that consumers and potential consumers perceive this difference as insignificant. And this is against the background of minds pre-occupied mixed (negative) perceptions on the performance of the product.

It can also be concluded from the study that E10's access by customers, especially those outside Harare is very limited. This has been caused not only by reluctance by fuel distributors (service stations), but also by wrong perceptions of the product's potential sales by the distributors. Green Fuel Ltd. has also not done much in getting the product pushed through to the market since the fuel market has become kind-a-liberalised.

RECOMMENDATIONS

Based on the above conclusions, the researchers make the following recommendations if the intended fruits of the mammoth project are still to be enjoyed:

Improve Consumer Access of E10 Fuel

The study proved that E10 is not readily available throughout the country. In the few areas outside Harare, E10 is mostly being sold through one service station. Some motorists have indicated that though they would like to try E10, they do not have access to the product. The study found out that most motorists are loyal with specific service stations unless there is a fuel crisis. Thus confidence could be built in such loyalists if E10 is being sold through their favourite pump. Thus E10 distribution should be improved through liaison with the distributors concerned. If possible, Green Fuel could integrate forward vertically towards the activities of its resellers i.e. open their own service stations and / or distribution centres / agents nationwide thus improve E10 access.

Market Education and Consumer Awareness

E10 advertisements rarely feature in the local media. A few pamphlets were only noted in some select service stations in Harare low density. Consumer awareness should be improved:

- ✓ This could be done through Trade Fairs, the use of public information dissemination tools such as newspapers, internet, workshops and forums.
- ✓ Engage the industry in forums and workshops. Offer them "Trial fuel" and encourage them to make some comparative experiments, give feedback thus helping Green fuel make improvements (adjustments) if need be.
- ✓ Make use of testimonials: The study proved that E10 commands a clientele base, composed of motorists who have become advocates of the product, especially the high class segment – why not use the satisfied consumer to convince another potential consumer thus *viral marketing.*
- ✓ Engage into nationwide *Green Movement Campaign,* educating the community on the benefits of using E10. Ensure that such campaigns receive both print and electronic media coverage.

Clarifying Technical Misconceptions

This could be done by pasting engine specification posters on service stations i.e. clarify all technical issues involved in the use of Ethanol Fuel. Specify engine compatibility issues and clear up all the misconceptions held by the market. The carburettor type of vehicles can handle 20 percent of ethanol blended fuel while the fuel injected can handle up to 90 percent with modifications i.e. with the use of conversion kits. In Germany, BMW, Mercedes Benz, Chrysler, Ford, Honda, Hyundai, Mitsubishi, Toyota, Jaguar and General Motors have all approved of the use of E10. [25] Are we using different models or is there any difference between Germany's E10 and Zimbabwe's? All this may have to be clarified.

The researchers strongly recommend a wide cross-media campaign to educate car dealers, motorists (drivers), technicians, journalists and other relevant stakeholders to dispel misconceptions and incorrect information about E10 and to highlight its benefits.

Addressing E10 Pricing Issue (Blend-Price Variations)

Green Fuel Ltd. should ensure that its position on price in clearly justified – 90% of the cost is still imported unblended petrol: this could be clarified during the consumer awareness campaigns. Alternatively, vary the ethanol blends to suit varying prices from, E5, E10, right through to E85. For instance, the study established that 75% of ethanol fuel advocates would not mind using higher blends as long they justifiably pay less.

Segmenting the Market

Europe and Australia have managed to package E10 as a 'premium super brand' thus it fetches a higher price than unblended petrol due to its performance and green benefits. [6] Advocates for Zimbabwe's E10 seem to be from middle to high class, arbitrating from the type of cars that fill and re-fill with E10. Thus Green Fuel could segment and target those locations where these classes reside and/or refill.

Mandatory Blending

Before the closure of the ethanol plant, Green Fuel had created over 4 500 jobs and empowered local village farmers by improving access to irrigation and contracting them to produce sugar cane for the plant. [26] The company would meet the nation's domestic requirements and export the excess, while generating about 120 megawatts of electricity. For a nation faced with a heavy fuel import bill, over 80% unemployment, critical electricity shortages; any efforts to create jobs and generate electricity should be seen as a positive development. Thus mandatory blending could be the lasting solution in the Zimbabwe's circumstances, not neglecting the prior recommendations.

Thisstudy has established that mandatory blending has been implemented in different parts of the world and it has worked. Preliminary resistance might occur but that should not derail the move, especially in view of the overwhelming benefits of the mammoth ethanol project.

Green Fuel Ltd. – Government - Industry Relations

Given the 'national status' of the project [2], it could be to the best interests of the all stakeholders involved to convert the project into a Private-Public-Partnership (PPP). Research has suggested that there is need for innovative research institutions, government and industry to establish linkages. [27] Based on the research findings, it is the researchers' view that the Green Fuel partners with the Government and / or key Oil Marketing Companies (OMCs) to enhance the E10 development and commercialisation efforts. This move could help overcome the anticipation that any mandatory blending 'would benefit an individual' [28] since the project becomes co-owned.

Target Export Market

Ethanol is 100% Zimbabwean i.e. produced by Zimbabweans for Zimbabweans, using Zimbabwean sugarcane. When all else has failed to improve its uptake locally, the researchers suggest that Green Fuel forms strategic alliances with leading regional oil companies to forge its market in countries such South Africa (where Mandatory blending has been documented), Botswana, Namibia and others. This comes from the realization that while some innovations may not do quite well locally, they could be having a "good" market waiting in another country.

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Development of mechanized poultry de-feathering process for small scale farmers in Zimbabwe

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ABSTRACT

Despite the increased participation by small scale players in the poultry industry in Zimbabwe, the small scale processing of poultry has remained highly manual, labour intensive and disjointed. In this paper, work on the design, development and optimization of the defeathering process for small scale farmers in Zimbabwe is reported. A rotary plucker of 700mm feather plate and 710mm tub diameter was designed and fabricated using locally available materials and machines. The optimisation of the process showed that a feather plate rotation speed of 180rpm, finger density of 104fingers/m^2, scalding temperature of 65□C, scalding and defeathering time of 60seconds and 30seconds respectively ensured 100% carcass quality at 99% degree of defeathering. It was concluded that a maximum batch size of 6 birds/ batch (>300birds/hr) can be processed from the processing unit and is a successful design constructed for application in Zimbabwe.

Key Words: poultry, de-feathering, design, plucker, small-scale farmer, scalding temperature.

INTRODUCTION

Prior to 1970, poultry processing was highly manual the world over with a very low production output per employee (1). Spurred by increasing consumer demand, new fast-food retail outlets and increasing urban population across Europe, Asia and America, new processing technologies emerged resulting in the increased output per employee at a rate of about 3% per year (1).Poultry meat consumption continues to increase at an annual rate of between 4 and 6% in the developed world and recorded a 35% increase from 2000 to 2008 (2). At 33% representation of the global meat consumption, poultry meat ranks second to pig meat (2), implying that sustainable processing technologies research and development will be key to human kind in this era. The post colonial era in Africa has also seen the increased poultry consumption patterns, mainly due to increasing populations and urbanization. The Zimbabwean poultry industry is reported to have drastically increased by a phenomenal percentage of over 400% from 2009 to 2011 (3). It was reported that

small scale poultry farmers contributed more than 65% of the poultry meat production, whilst capital intensive multinational companies contributed 35% of production (3, 4). Despite the market boom, the viability of small scale poultry production is threatened by the highly manual, labour intensive, inefficient and costly processing operations. Solving the challenge through securing outgrower contractual agreements with vertically integrated large scale multinational companies has borne little benefit to the small scale grower and hence the need to adapt and develop small scale processing technology to bridge the gap.

Poultry processing takes several demanding processes such as pre-slaughter activities (catching and transportation), stunning, bleeding, scalding, plucking (defeathering), evisceration, packing, chilling, refrigeration and distribution. Scalding and defeathering are the most critical operations in poultry processing as they significantly affect the quality of the poultry product (5).The large scale processing operations (>5000 and up to 30000 birds per day) are capital intensive, and often too big, rendering them irrelevant to small scale operations (1, 6).Although defeathering processes that are pertinent to small scale producers (100-5000birds per day) which include the Whizbangplucker, table top plucker, drum bench type and tilt bowl type of plucker are in operation the Americas, Europe and some parts of Asia(7, 8), application in sub-Saharan Africa and particularly Zimbabwe is very minimal.

Few and isolated small scale imported technologies have started trickling into the market, but they present several challenges to the local customers. One of the major problems has been the high purchasing costs associated with importation. Technical challenges exist in the operation of the imported equipment resulting in skin tears, meat damage (9, 10) and low feather removal efficiencies. The pluckers have also been grossly underutilized due to optimization related challenges. Moreover, the durability and maintainability of such equipment does not suit local farmers as the material is exotic and the expertise lacking. The operational challenges are worsened by the fact that critical defeathering parameters like scalding temperature and time as well as defeathering time vary with breed type and from place to place (5, 9, 10, 11, and 12). The wear rate of fingers has also been a major area of concern and work is in progress all over the world to improve performance and durability (13). The high consumption of water in existing defeathering technology has led to continuous research into dry plucking technologies like microwave scalding (14).

With Zimbabwe going through the agrarian reform and economic empowerment phases, policies have been formulated that embrace technology through value addition and increased productivity. The government is spearheading efforts to safeguard the local industry, guarantee employment

creation and eliminate trade imbalances in the poultry sector (e.g. imports from Brazil, Argentina and South Africa). The efforts of the government are being observed in the small to medium enterprises units as output is steadily rising. Globalization has effected new strategies of survival for players in the developing world and among them technology transfer. However a one size fits all approach is not effective; innovation therefore should be utilised to augment the transfer process. Research and development of suitable machines for small scale conditions of the Zimbabwean producer is necessary. Of concern to the local farmer are robust defeathering machines that optimisedefeathering efficiency, carcass quality, capacity utilization and the health and safety aspects of poultry processing. The relevant technical skills need to be supported to ensure a wholly indigenous process and eliminate need for expensive outside expertise. The uniqueness of each location does not warrant use of a single product or optimized process. The environment plays an important part in the selection of a suitable process. Alternative environmentally friendly energy to power technology exists to comply with the demanding requirements of environmental authorities and the emerging green and sustainable production demanded by markets. Off grid/ remote areas have tapped into mini-hydro power, solar energy, biodiesel (jatropha) and made the most of enhanced waste management strategies that include use of biogas to heat water for the scalding process. Oumaru et al., 2010 (15) reported that poultry manure ranked first above cattle and pig manure in the production of biogas, which could be used as a clean source of energy for sustainable poultry operations. Work done by Formentini et al., 2011(16) in Brazil showed that biogas from poultry could reduce the energy bill on a slaughterhouse by 3.89%.

It is against this background that the local development of a small scale defeathering technology is justified with the aim of enhancing the viability of small scale poultry production by addressing the existing challenges.

Aim and Objectives

In this paper, work on the design, development and optimization of the de-feathering process for small scale farmers in Zimbabwe whilst maximizing the utilization of locally available resources is reported. The objectives of the work were:

1. To fabricate and assemble a 300 birds per hour (bph) defeathering process technology for small scale farmers in Zimbabwe.
2. To optimize the scalding process and the plucking process.

METHODOLOGY

Batch sizes of 60 Ross type broiler chickens weighing from 2.5 to 3kg (live weight) from a selected small scale farmer were used for the work. Live birds were taken from the batch and slaughtered manually using a sharp knife. The birds were allowed to bleed for 90s before being scalded in a tank at temperatures ranging from 50 - 80°C for periods ranging from 30 to 180s (5, 10, and 12). After scalding, the birds were immersed into cold water at temperatures ranging from 18 - 20°C for 5s to preserve skin quality (10). The birds were then carefully placed in a locally made rotating plucker*(tub-Φ760mm x 600mm; f/plate – Φ700mm, 120fingers)* and the plucker rpm was varied between 200 and 1400rpm.The plucker tub and base were made from 1mm food grade stainless steel sheets and the fingers from rubber. The plucking was allowed to run until plucking was complete or some irregularity that warranted stoppage was observed. Each run was repeated thrice to ensure reproducibility (5, 10). The time to stoppage was recorded using a stopwatch. A small amount of water was sprayed in the tub of the plucker to clean up the carcasses of the feathers and to help as lubrication to avoid skin damage. Defeathering efficacy, which refers to the effectiveness of feather removal as depicted by the percentage bird area clear of feathers to the total bird area covered with feathers before removal is one of the major quality attributes of an effective and efficient defeathering process. It was measured by estimating the ratio of the area defeathered to the total feathered surface area of bird before defeathering. Carcass quality is even far more critical as it refers to the extent of possible damage inflicted on the carcass of the bird due to the defeathering process. The damage on the carcass was classified and quantitatively weighted into major and minor damages. The major damages were classified as those on the main body of the carcass like the wings and the drumsticks. The minor damages referred to those of the legs and other peripheral parts with minor impact to the overall quality and value of the main carcass. The load on the machine was measured using a tong tester.

RESULTS AND DISCUSSION

Effect of rotating speed on defeathering efficacy and carcass quality

Defeathering efficacy and carcass quality were the key performance parameters in the optimization process. The effect of the rotational speed of the featherplate on carcass quality and defeathering efficacy was therefore investigated.

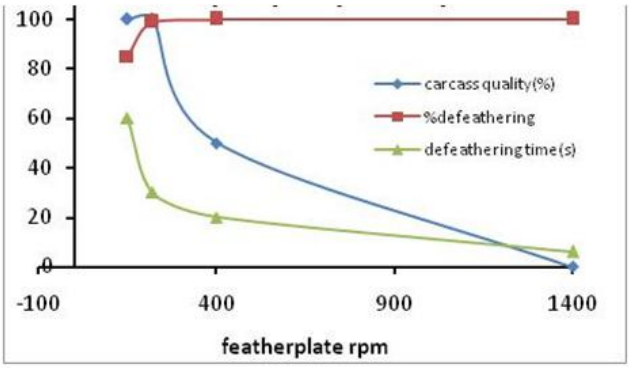

Figure 1: Effect of rpm on defeathered bird quality

The plucker was tested for defeathering efficacy and carcass quality for various featherplate rotating speeds as shown in Figure 1. Higher speeds tended to make defeathering complete but at the expense of carcass quality which exposed the skin and flesh to tears and breakages due to high centrifugal forces experienced during defeathering. Lower speeds slightly reduced the defeathering efficacy and defeathering time. However carcass quality was high attributable to low centrifugal forces resulting in minimal damages. An rpm of 200 yielded optimum results of defeathering efficiency (>99%) and carcass quality of 100%. The optimum rpm was similar to the one reported elsewhere (10).If tender fingers can be designed, higher speeds with minimal damage to carcass can be achieved with the benefit of increasing throughput. Van Hung et al., 2011 reported the use of 340rpm using disc type plucking machines (5).

Effect of scalding temperature on defeathering efficiency

Scalding temperature is one of the critical process parameter that must be controlled to ensure good poultry product quality (5, 9, 10) and hence the need to research on the effect on defeathering efficacy and carcass quality. It is reported that most of the product challenges observed after defeathering can be traced back to the scalding process [9].

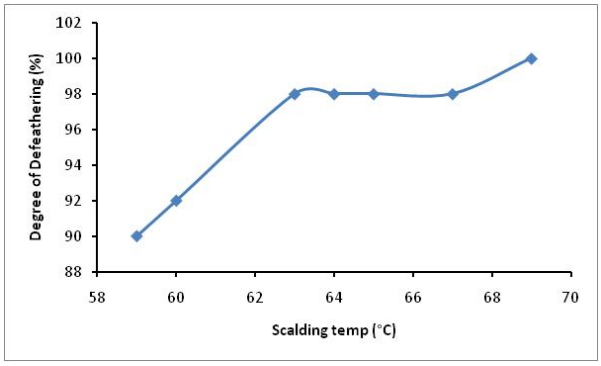

Figure 2: Effect of Scalding Temperature on Defeathering Efficacy

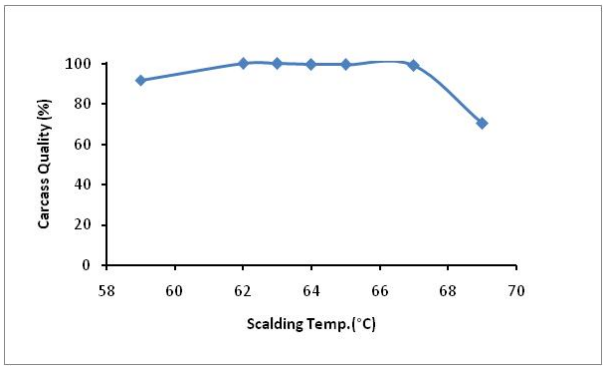

Figure 3: Effect of scalding temperature on carcass quality

Figures 2 and 3 show that an increase in scalding temperature from 58°C increases defeathering efficacy from 90% to 100% albeit at the detriment of carcass quality at temperatures above 66ºC. Fig 3 also shows that an increase in temperatures above 68°C yields rapid fall in carcass quality. Increased scalding temperatures yielded discoloration in the final product and at worst major carcass damage like skin tears and broken wings and feet. It was observed that the best scalding temperature for acceptable carcass quality was in the range of 60-66°C and was consistent with results obtained elsewhere (12). However results reported by Van Hung et al., 2011 and Onawumi et al., 2012 report of higher scalding temperatures (>66ºC). This could be attributable to different poultry breeds as well as different operating environments (equatorial climate as compared to the savanna climate).Defeathering was also correlated to the amount of time the birds were scalded. The immersion time was measured from 30s to 180s for various batches and no considerable advantage was evident for longer immersion periods. The longer periods tended to increase carcass damage and discolouration at temperatures exceeding 68°C. An optimum time of 45s was found to yield acceptable results consistent with results reported by Maja et al., 2007 (12). However, scalding times greater than 60s were reported elsewhere, 60 to300s (5, 10, and 11). These variations could be attributable to several factors such as breed variation, method of heat distribution to birds during scalding as well as the varying climatic change (17). Shorter scalding times would be exciting since they reduce throughput time. Further work is required in the use of high scalding temperatures for short periods of time. Microwave scalding, which eliminates the use of water and kills deadly bacteria (14) could be investigated as a novel cleaner and cost effective defeathering process technology.

Effect of batch size on defeathering efficacy and carcass quality

The capacity of the plucker is measured as the number of birds defeathered per run in a specified time. This measurement is critical as it determines the overall capacity of the machine. The number of birds defeathered per run is referred to as the batch size.

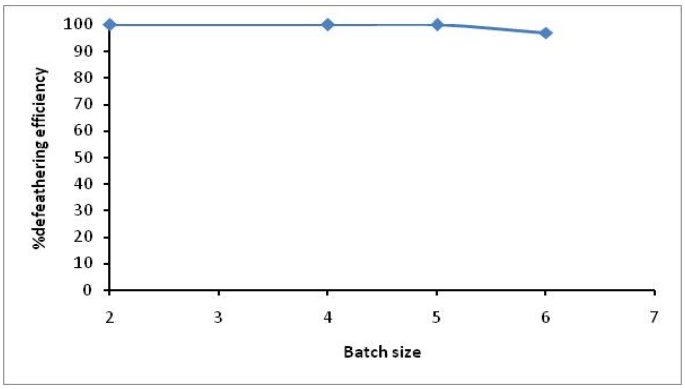

Figure 4: Effect of Batch Size on Defeathering Efficacy

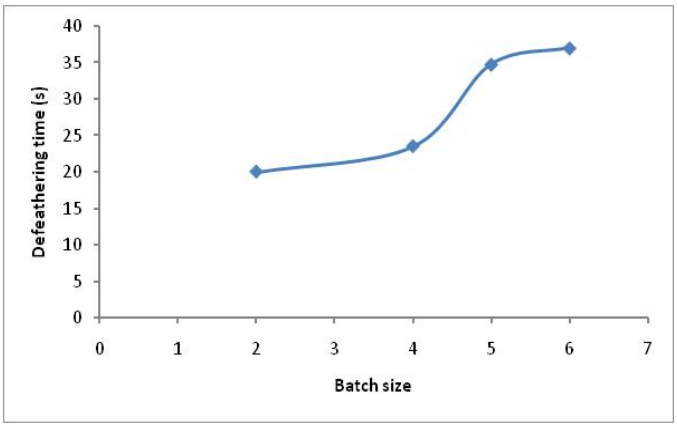

Figure 5: Effect of Batch Size on Defeathering Time

Figure 4 shows that from a batch size of 2 to 6, there was no significant change of defeathering efficacy with increasing batch size. However there was a general increase in defeathering duration with increasing batch size from 2 to 8 as shown in Figure 5. The optimal defeathering time ranged from 20 - 37s. At batch sizes greater than 6 birds, the defeathering time increased significantly whilst the defeathering efficacy reduced. This was attributable to limited free play/rotation of the birds on the featherplate due to congestion. A critical feather plate utilization beyond which free rotation/play of the birds is limited therefore exists.

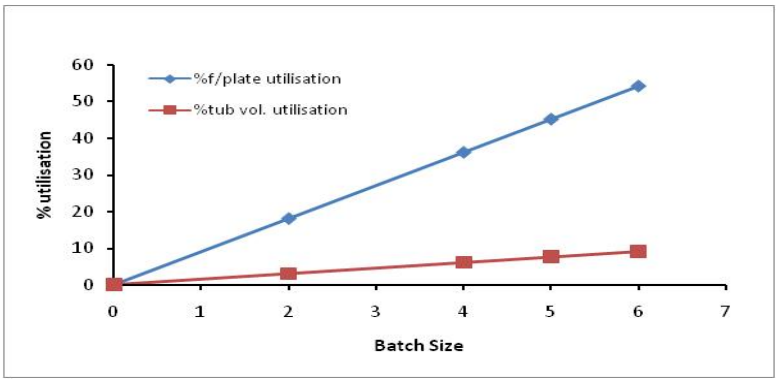

Figure 6: Relationship between Batch Size and Defeathering Machine Space Utilisation

Figure 6 depicts the relationship between batch size and plucker space utilization in terms of plucker tub volume utilized and the feather plate area utilized. The featherplate utilization was calculated as the ratio of the total surface area covered by the chickens to the total surface area of the birds. Similarly, the utilisation of the tub was calculated as the ratio of the total volume occupied by the birds in the tub to the total volume of the tub. The featherplate utilisation was very low at 18% for a batch size 2, whilst the maximum possible feather plate utilisation was 54% corresponding to a batch size of 6 birds (15 – 18kg). Each bird had an average surface area of (~348cm^2 – *29cm x 12cm*) and volume of (~0.0042m^3). Above the batch size of 6 birds, there was limited free play required for the plucking process to proceed. The utilisation of the plucker tub was very low, ranging between 3% and 9%. This low tub utilisation implies a lot of material wastage. Stainless steel is expensive and hence there are opportunities to reduce the volumetric size of the tub and hence reduce the cost. Featherplate utilization could be improved by modification of defeathering fingers (13) amongst other initiatives. It is also important to note that given the bird surface area and volume, the plucker tub volume and featherplate surface area can be predetermined at the design stage using simple mathematical formulae, if the maximum tub and plate utilization are known.

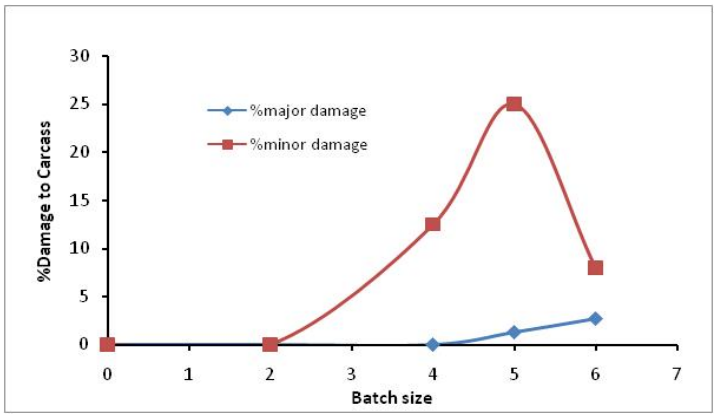

Figure 7: Effect of Batch Size on Carcass Quality

The effect of batch size on carcass quality is presented in Figure 7. There was no damage to the carcass at a low batch size of 2. No major damage to the carcass was observed at batch sizes of up to 4. However major damages *(especially of wing and drumstick)* were observed for batch sizes greater than 4. Nevertheless, the maximum major damage was minimal at 3%, observed for a batch size of 6birds. The damage was attributable to birds being trapped in the gap between tub and feather plate. It can be concluded that within allowable operational range, the effects of batch size on carcass quality are minimal. The recurrent minor damages were that of breakages to legs, with the highest being 30% for a batch size of 5. There seems to be no clear relationship between minor damages and the batch size above a batch size of 2. This could be due to the fact that the entrapment

of legs in the gap is random in nature as the birds rotate in the plucker. Nevertheless, the probability of entrapment may increase with the batch size as more birds tend to push each other towards the gap as they rotate. The breakage of legs was caused by the sharp feather plate edge which would cut the legs as they get trapped in the gap.

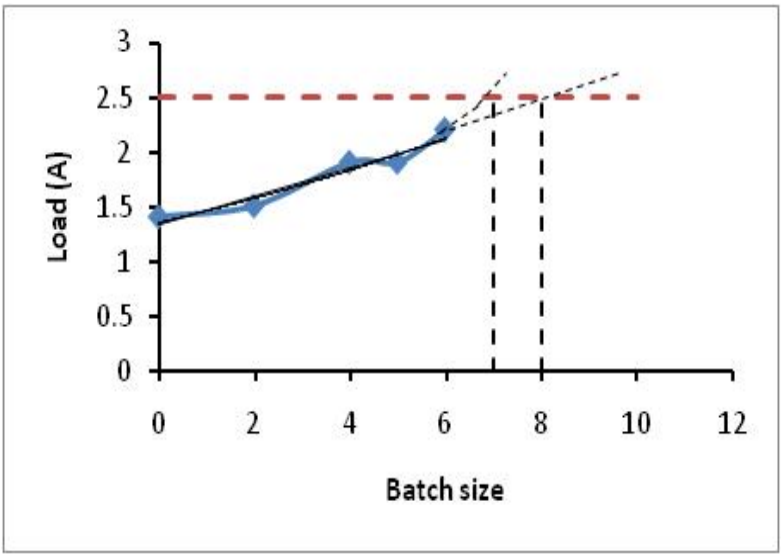

Figure 8: Effect of Batch Size on Electric Motor Load

The average no load current of the poultry plucker was 1.3A which is consistent with the expected no load current of the electric motor (Figure 8). It implies that the featherplate and power transmission system was perfectly assembled and aligned. The minimum batch of 2 birds drew an average load of 1.5A at 60% motor utilisation whilst the maximum batch of 6 drew an average of 2.2A at 88% motor utilisation. By interpolation of the graph presented in Figure 8, it can be shown that the maximum batch size the electric motor can handle must be less than or equal to 8 birds (Figure 8). Maximum electric motor utilization implies high energy efficiency and will result in reduced cost of defeathering machines since smaller electric motors can be used to achieve high capacities. Therefore there is need to match the size of the electric motor to the batch size when designing defeathering machines. As it has been earlier shown that that the featherplate size is also a limiting factor to capacity utilization, there is need to synchronise featherplate size to electric motor size to ensure optimal design of defeathering machine.

Effect of defeathering time on defeathering efficacy and carcass quality

Plucking time is a critical parameter affecting the effectiveness of defeathering as well as the quality of the carcass. It is widely reported that too long plucking times result in carcass quality deterioration whilst too short a plucking time results in low defeathering efficacy (5, 9, 10, and 11).

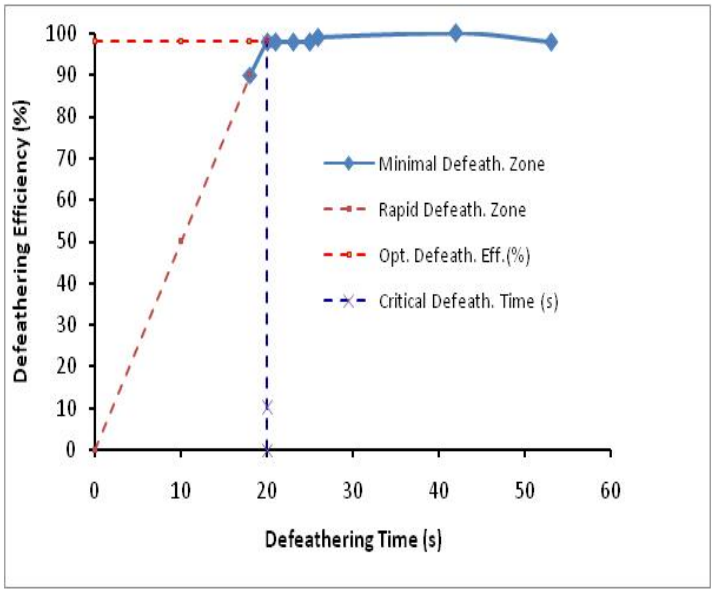

Figure 9: Effect of Defeathering Time on Defeathering Efficacy

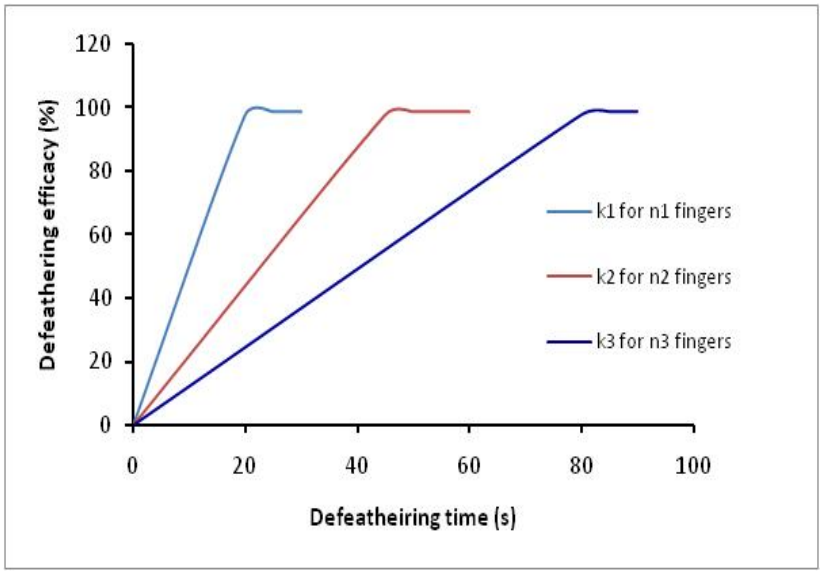

Figure 10: Effect of Defeathering Time on Defeathering Efficacy

Figure 9 shows that significant defeathering efficacy (>90%) was generally observed from a plucking time of 18seconds and above. There also existed a critical defeathering duration above which the degree of plucking remains constant. The maximum degree of defeathering achieved was 100% and 98% with and without addition of a gentle spray of water respectively. The degree of defeathering was constant in the defeathering time range of 20 to 52 seconds. It implies that any defeathering effort after a defeathering time of 20s does not have any significant contribution to improving the degree of defeathering. Therefore, beyond the critical defeathering time, the cost of defeathering might increase without adding any significant value. In the same manner, the

production rate is reduced without necessarily adding value to the defeathered bird. Below the critical defeathering time, there seems to be a direct relationship between the defeathering time and defeathering efficacy as shown in Figure 9. However the nature of this relationship needs further investigation. It might be hypothesized that the constant of proportionality of the relationship between defeathering time and defeathering efficacy could be dependent on the number of fingers (finger density), the speed of rotation as well as bird density (Figure 10).

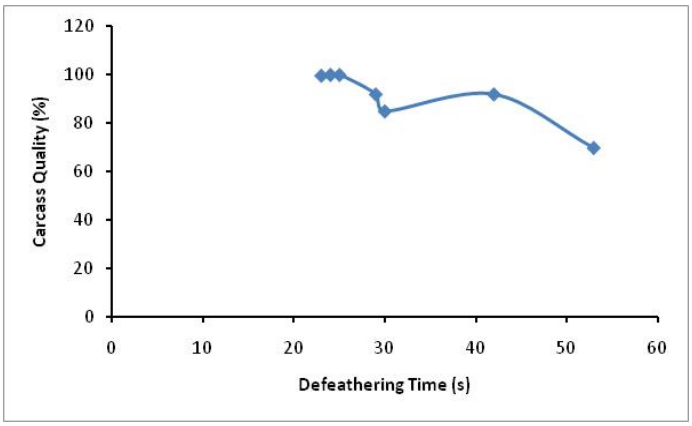

Figure 11: Effect of Defeathering Time on Carcass Quality

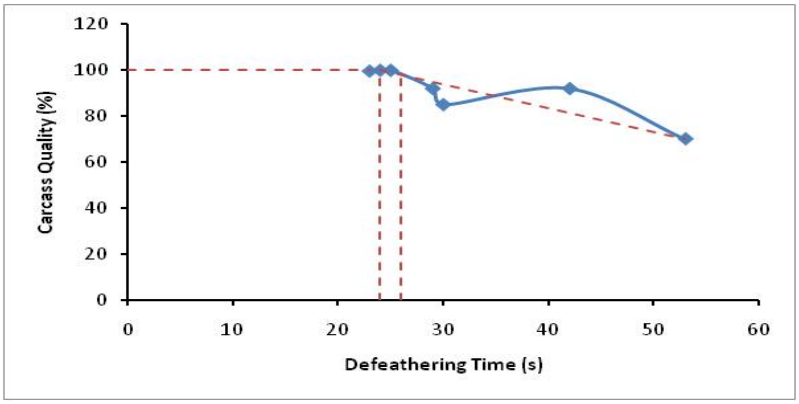

Figure 12: Effect of Defeathering Time on Carcass Quality

As Figures 11 and 12 show, the quality of the carcass deteriorates beyond a critical defeathering time. This could be attributable to the plucker fingers brushing directly against the exposed skin of the carcass after most feathers have been removed. Below the critical defeathering time, the carcass is undamaged and hence 100% quality. However, beyond the critical defeathering time, T_c, the quality of the carcass begins to deteriorate with time.

Optimisation of the defeathering process

Compounding the results for all the experiments yields figure 13; which shows that a scalding temperature of 65°C, immersion time of 45s and plucking time of 25s yielded the optimum

conditions for the Ross type breed under Zimbabwean conditions taking into cognizant various factors such as defeathering time, efficiency and carcass quality. The process required a minimum of 5 operators manned at various points of the processing line, two people proved adequate for the slaughtering and breeding process, two at the scalding and dipping units and one person operating the defeathering machine. The capacity of the process was 6birds in 30s at a defeathering efficacy of 99% and carcass quality of 100%. Automation of the process could result in significant savings in time in bleeding and scalding. Savings can also be realized in the water usage.

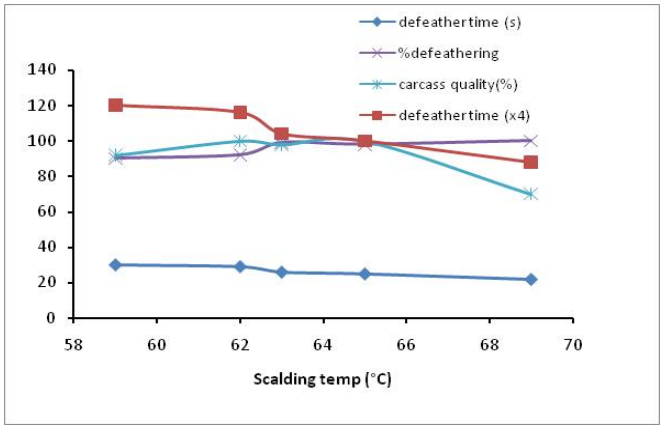

Figure 13: Optimisation of the Defeathering Process

CONCLUSION

The following conclusions were deduced from the scalding and defeathering experience. The plucker can handle up to a maximum batch size of 6 birds *(2.1 – 3kg live weight, 42cm length and 20cm diameter)* at a maximum capacity utilisation of the feather plate of 54% and 88% electric motor loading *(1.1kW, 3phase)*. The tub capacity utilisation was very low at 9 % implying that there is great opportunity to reduce the volumetric size of the tub and hence save on materials. Therefore given the weight and size dimensions of the birds, it is possible to design the tub and feather plate sizes, as well as matching them to the electric motor size. Major damages to the carcass were minimal (<3%) implying that the plucker is capable of producing high quality carcass.

Scalding temperatures in the range of 60 - 66°C are suitable for pretreating the birds before defeathering, resulting in defeathering efficiencies close to 100%. Defeathering efficiency improves with increase in temperature from 60 to 67°C. The defeathering efficacy also increases with increase in the defeathering time. However, beyond a certain plucking time, the quality of carcass deteriorates; therefore optimisation has to be done. Addition of a spray of water also improved defeathering efficiency from 98% to 100%.

RECOMMENDATIONS

The depleting energy reserves and green revolution initiatives make it ideal to explore alternative power for scalding and plucking (e.g. renewable – biogas, biodiesel, solar, etc) (15,16) as demand for energy in Africa is rising. In addition the processing yields valuable by products that can be tapped for useful energy. Water recycling can be used for the scalding and defeathering processes as considerable amounts of water are used (18). Treating the water ensures continued use and reduces the water footprint of the process (11, 18). Microwave scalding (14) takes the initiative further as it improves drastically the water used to very negligible amounts. It also has the added advantage of low evaporative losses. New biotechnology aspects of breeding techniques such as featherless breeds need to be employed for Zimbabwe; this significantly reduces the burden of feather removal such as energy consumption during scalding and defeathering and the hassle of disposing feathers safely. Further work is also necessary to come up with alternative material for fingers and plucker tubs to ensure machines are easily accessible to local producers at cheaper prices. The cost of material warrants that a tradeoff to be reached for finger density and production (batch) capacity. This is heavily dependent on defeathering machine sizes and the sizes of available birds for defeathering.

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The growth response of coffee plants to organic manure, inorganic fertilizers and integrated soil fertility management under different irrigation levels

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Abstract

A study was carried out to determine effects of organic, inorganic fertilizers and integrated soil fertility management and irrigation levels (1000ml, 750ml and 500ml per planting station) on coffee growth. There were no significant differences ($p>0.05$) in girth, leaves and primaries due to the different soil fertility management options. Significant differences ($p<0.05$) due to soil nutrient sources were observed in coffee height where inorganic fertilizer treatment resulted in tallest coffee plants (47.4cm) and integrated soil fertility having the shortest coffee trees (42.8cm) after one year. The highest irrigation level of 1000ml had the tallest plants with thickest stems while the lowest level had the shortest and thinnest plants ($p<0.05$). No significant differences were observed in number of leaves and primaries due to irrigation treatments. Results indicate that inorganic fertilizers are most effective at high irrigation levels while organic manure perform better than inorganic fertilizers under low irrigation water levels.

Key Words: coffee plants

INTRODUCTION

Soil fertility management and water supply are important for successful crop production in all agricultural commodities. The use of inorganic fertilizers has been a significant contributor to increased crop productivity since the green revolution, and has resulted in reduced use of organic nutrient sources that farmers have relied on for centuries (1). The quality of fertilizers, their costs and yield contribution are as variable as their sources. The most common sources of organic manure used in crop production are livestock dung, composted and green crop residues, farmyard matter and organic manure from natural systems and material production systems (1; 2).

The need for renewable, locally available and cheaper options for supplying nutrient to crops is increasingly becoming important because of the need for sustainable agriculture (3-5). With growing demands for sustainably produced agricultural produce for environmental, social and food safety reasons, the use and recycling of organic matter is becoming inevitable, particularly for export market depended commodities such as coffee.

Sustainable agriculture is a production process and farm management system that has positive economic, ecological and social benefits in the short and long term (6). The levels of sustainability varies on a sliding scale from the strict organic farming methods that demand perfect quality of the production process and the environment to general guidelines and codes of conduct on various aspects of the expectations of the production system (6; 7). Use of organic soil fertility options is among the key attributes of sustainable agriculture. Maintaining physical, chemical and biological soil properties for plant growth and environmental efficiency requires the input of organic matter that is decomposed into nutrients and used up by plants. Sustainable production is becoming a necessity for coffee sectors to remain competitive in the global trade against oversupply and price fluctuations that in some years result in coffee price crisis.

Reliance on inorganic fertilizers may not be sustainable in the long term given that soils may lose microorganisms, become acidic and having unstable aggregates leading to erosion and general degradation, and this may explain yield decline with time despite consistent use of inorganic fertilizers (5). Studies on the potential of using organic nutrient sources in coffee production identified cattle manure as the most promising (2; 8; 9) while recycling coffee wastes such as pulp and prunings as direct inputs or in combination with green manures and live mulch in nutrient management were effective in promoting coffee growth and yield and also economically viable (10).

On the other hand, some studies have shown that organic manures are very important for maintaining soil organic matter and supplying nutrients to the coffee systems but may not be enough for balanced plant nutrient flows and for achieving profitable yield levels (11). This is because the maximum N obtainable from common organic manures is less than 10%, P less than 2% and K and less than 10% of dry matter compared with high nutrient outflows of up to 105kg ha^{-1} of N, 13kg ha^{-1} of P and 107kg ha^{-1} of K to achieve yield levels of 1t ha^{-1} per year resulting in serious negative nutrient balances (12; 13). Given that the negative nutrient balance from use of organic manures is only apparent in yielding coffee, it maybe that organic manures or at least integrated are able to provide a positive nutrient balance when the coffee has not reached bearing age.

Water supply is increasingly becoming important in coffee production given the unreliable rainfalls and frequent droughts that affect growth, yield and quality of coffee (14; 15). According to Coffee Management Services (16), irrigation is an expensive management practice because it involves pumping costs, labour and other equipment requirements. This is despite the fact that soil water is important for keeping plant nutrients in solution, maintain soil microorganisms, and for root and shoot development and functioning all of which have a bearing on production levels and quality (11). Studies on irrigation levels and N rates of pomegranate and coffee showed that the high rates of N are effective when there is minimum water depletion (17; 18). This indicates that with limited water supply such as in cases of drought, N and probably other nutrients are not easily available from inorganic sources of soil nutrients.

Soil organic matter plays an important role in moisture retention and therefore the use of organic manures is considered as a climate change adaptation strategy. Soil moisture is important for the decomposition of organic matter and making nutrients from both organic and inorganic fertilizers available to the plant (19). Irrigation water management is very critical in coffee production. Excessive irrigation is costly and moisture stress results in dieback, wilting and opportunistic disease and pest attacks, resulting in reduced production in both cases. Depending on the timing, moisture stress can also result in floral abortion, which results in reduced yields. The interaction between sources of nutrients and irrigation levels is therefore very important especially in the context of reducing production costs and adapting to climate change in the coffee sector. Soil fertility management and irrigation water supply are therefore two important management functions in coffee production.

OBJECTIVES

The objectives of this study were to establish the growth effects of different soil fertility management options and irrigation levels on coffee vegetative growth, which has direct implications to coffee yield and quality. Additionally, the synergistic effects of soil fertility management and irrigation levels were also investigated in order to identify if organic soil fertility management can sustain coffee growth when water supply is low by improving soil moisture conservation and water use efficiency. This information is important in building a productive, sustainable and robust coffee production system under challenges of environmental accounting and reduced rainfalls in rainfed systems due to climate change.

MATERIALS AND METHODS

Study Sites and Treatments

The experiment was carried out at Coffee Research Institute, Chipinge, Zimbabwe ($32^0 39^/$W, $20^0 13^/$ S and altitude 1100m above sea level). Healthy coffee seedlings (variety Catimor 129) that were six months old were transplanted into five litre earthen pots. The seedlings were stripped of their initial soil and then planted in media that contained the different soil fertility treatments. The treatments consisted of organic, integrated and inorganic fertility management options.

The organic manure treatment contained composted humus obtained from under a forest after clearing fresh litter. Sieved 3kg of humus were mixed thoroughly with 2kg of soil media then the coffee seedlings planted. For integrated fertility option, 1½ kg of humus were mixed with soil humus and 25g of inorganic fertilizer (15:5:20 NPK) mixed in the soil before planting seedlings. The inorganic fertilizer treatment had 50g of inorganic fertilizer mixed with soil before planting coffee seedlings in the soil media. The media which was mixed with the fertility treatments was topsoil obtained from an old fallow. The soils at the institute are orthoferallitic according to the Zimbabwe Classification System, derived from UmkondoQuartzites&shales and consist of deep, fine-to-medium grained sandy loams on the surface (20).

Trial Set Up

The fertilizer application rates for the inorganic and integrated fertility management treatment were calculated from the published rates of inorganic fertilizer recommendations for young coffee in the field which are 1t ha^{-1} per year (21). At a plant spacing of 3m x 1.5, a plant population of 4450 plants ha^{-1} will be obtained using double covas and therefore half the rate per plant will give 50g per planting station. All soil fertility treatment applications were repeated after 6 months. Three water levels were used as irrigation treatments. These were a high rate with 1000ml, a moderate rate with 750ml and low rate with 500ml. All the water treatments were applied bi-weekly.

Measurements and data analysis

Measurements were taken on a bi-weekly interval on counts of number of leaves (recorded for the first 6 months), girth measured at 5cm from the surface using a Vernier callipers, height measured to apex leaf using a metre rule and counts of number of primaries for one year. Counts of number of leaves and number of primaries were log transformed before statistical analysis. Repeated Measurements Analysis of Variance was used to determine the significance of the variance between treatments on the data recorded over time (Mean) and Analysis of Variance was used for analysis of final recording of data (Final) in Genstat 14 software (VSNI, 2011) and linear regression and analysis of covariance were done in Excel and R.

RESULTS

Effects of soil fertility on coffee growth

Effect of fertility option on coffee biometric characteristics

Inorganic fertilizer produced the tallest coffee seedlings ($p<0.05$) with a final height of 124.8cm. Combining inorganic and organic fertilizers performed better than just organic fertilizers alone in both the mean height and the final height of the coffee seedlings. Organic manure resulted in the shortest coffee plants with a mean height of 42.8cm and a final height of 78.6cm (Figure 1). Mean and final coffee stem thickness did not significantly respond ($p>0.05$) to soil fertility treatments (Figure 2). There were no significant differences ($p>0.05$) due to soil fertility treatments in mean and final number of leaves and number of primaries (Table 1).

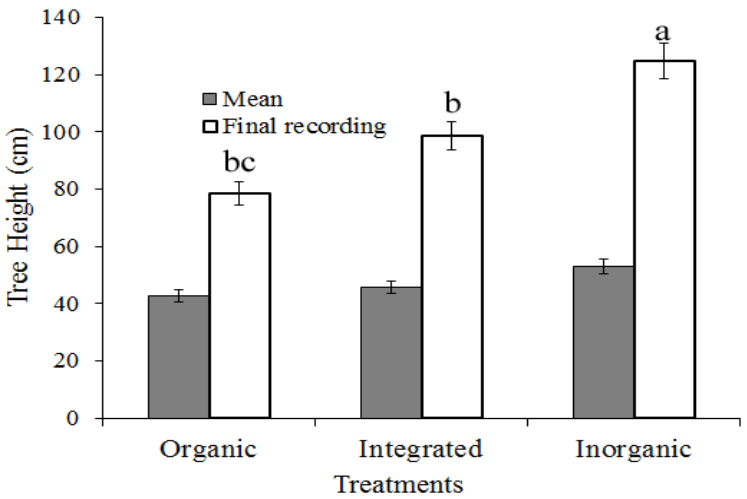

Figure 1: Effect of soil fertility options on coffee height (treatments with different letters significantly different after Tukey test ($p<0.05$))

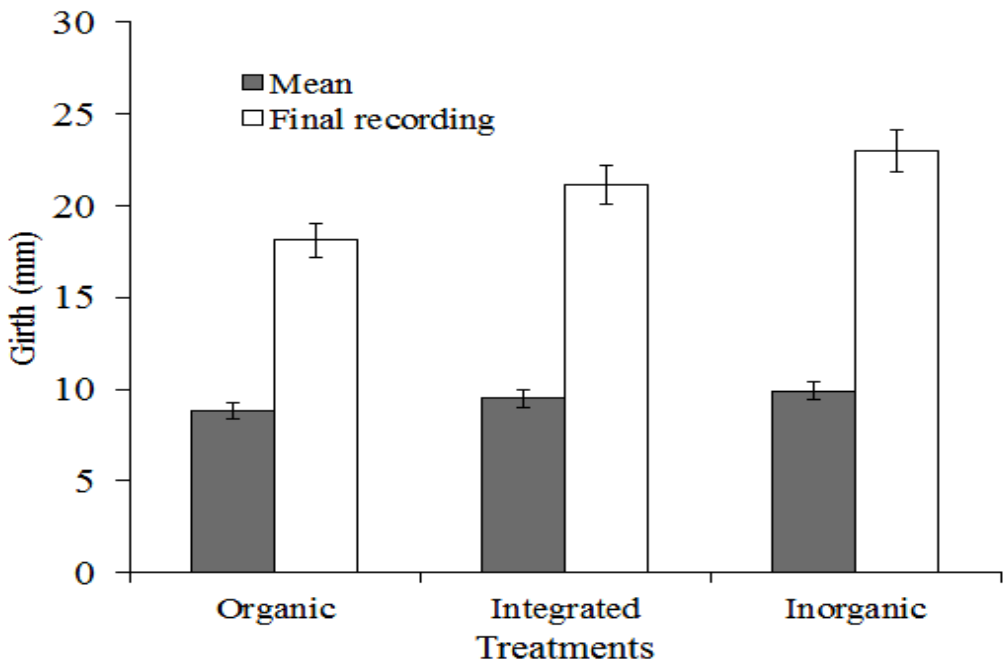

Figure 2: Effect of soil fertility option on coffee girth

Table 1: Effects of treatment on number of leaves and branches

Treatment	Number of leaves		Number of primaries	
	Mean	Final	Mean	Final
Inorganic	14.9	19.8	8.4	17.1
Integrated	14.3	18.7	8.7	18.2
Organic	15.5	20.8	8.9	17.7
p	0.364	0.282	0.082	0.115

4.1.2 Effects of soil fertility options on the growth partitioning

There was evidence in proportional growth of girth, number of primaries and height when coffee plants are under organic manure ($p<0.05$, Table 2). This partitioning was not apparent under inorganic fertilizers as none of the relationships were neither strong nor significant. The strongest proportional growth was between height and girth under organic manure ($r^2=0.77$, $p<0.05$). Under integrated soil fertility management, the relationship between girth and number of primaries was significant ($r^2=0.46$, $p<0.05$). Examination of the relationships indicated that under inorganic fertilizers, there is more growth of primaries at the expense of girth and height, and more height at the expense of girth (Figure 3g-h).

Table 2: Growth partitioning due to soil fertility treatments

Treatment	Factors	r^2	*p*
Organic	Primaries and height	0.52	0.0293*
	Girth and primaries	0.37	0.0848
	Height and girth	0.77	0.0018**
Integrated	Primaries and height	0.058	0.5327
	Girth and primaries	0.46	0.0453*
	Height and girth	0.004	0.8677
Inorganic	Primaries and height	0.23	0.1913
	Girth and primaries	0.16	0.2801
	Height and girth	0.18	0.2589

4.1.3 Effects of soil fertility options on the growth patterns

Coffee plant girth, number of leaves, height and number of primaries showed a very strong (r^2>0.9) linear growth over time (Table 3). Analysis of covariance showed that there was no significant differences between the slopes of girth, number of leaves and number of primaries (p>0.05) between organic, integrated and inorganic fertilizer options over time.

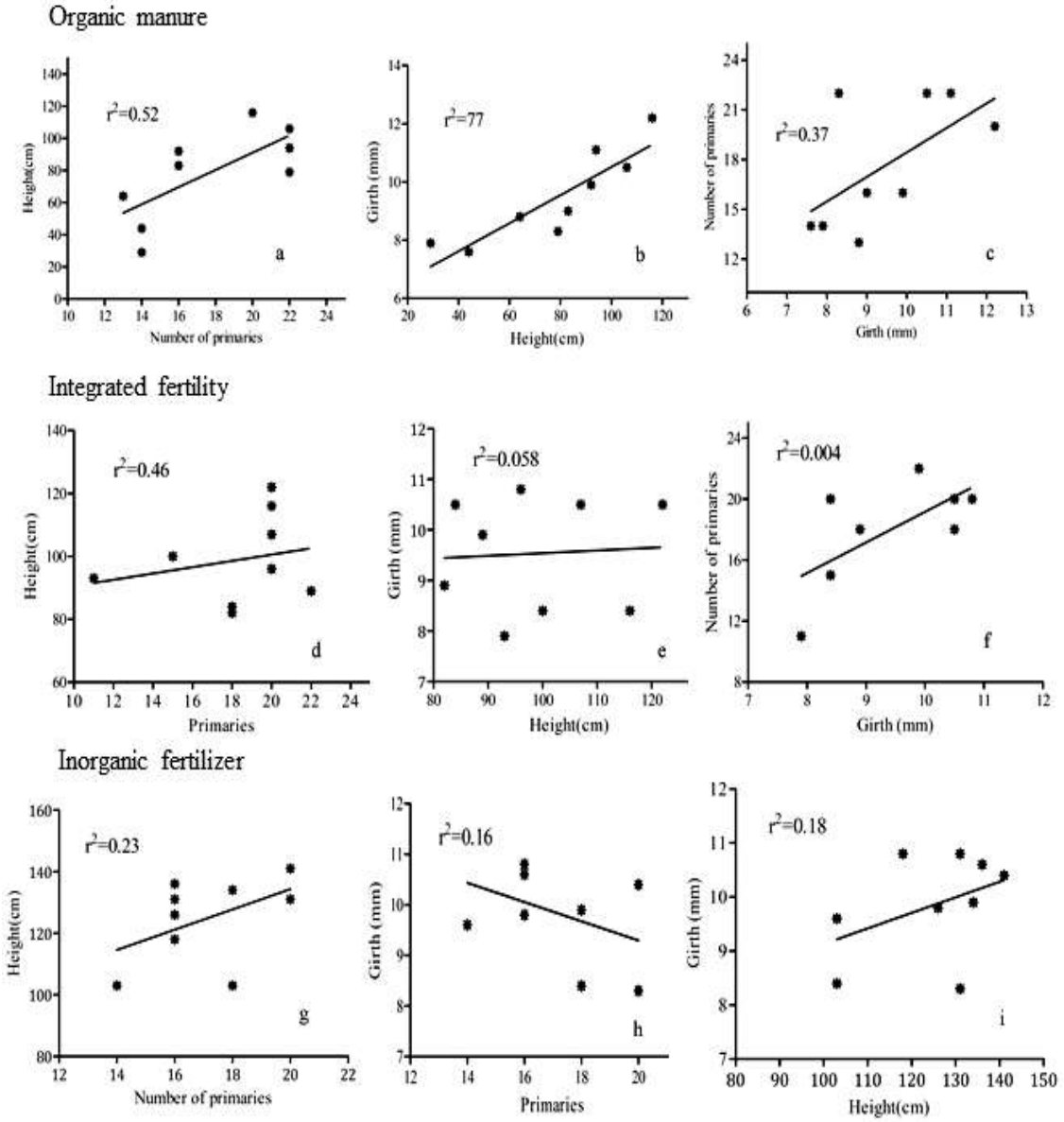

Figure 3: Coffee growth partitioning between number of primaries, height and girth under different fertility options

Table 3: Growth functions for each of the treatments for girth, leaves, primaries and height

Attribute	Treatment	R^2	*p*	Function
Girth	Organic	0.98	<0.001	y=0.15x+2.4
	Integrated	0.98	<0.001	y=0.15x+2.5
	Inorganic	0.99	<0.001	y=0.16x+2.5
Height	Organic	0.96	<0.001	y=0.79x+13.1
	Integrated	0.95	<0.001	y=0.68x+15.2
	Inorganic	0.94	<0.001	y=0.85x+13.8
Leaves	Organic	0.97	<0.001	y=0.45x+8.1
	Integrated	0.96	<0.001	y=0.46x+7.4
	Inorganic	0.97	<0.001	y=0.51x+7.9
Primaries	Organic	0.98	<0.001	y=0.23x-1.7
	Integrated	0.96	<0.001	y=0.23x-1.4
	Inorganic	0.93	<0.001	y=0.24x-1.6

Effect of water levels on coffee growth

Effect of water levels on biometric characteristics

The young coffee plants significantly responded ($p<0.05$) to irrigation water amounts in terms of height and girth. Coffee plants were tallest (118.6cm) and had thickest plant stems (10.2mm) when supplied the more irrigation water levels and shortest (89.9cm) and thinnest (8.8mm) under the lowest irrigation amounts (Fig 3a and 3b). In terms of number of leaves and number of primaries, there were no significant differences ($p>0.05$) due to different irrigation levels (figure 3c and 3d). The coffee plants developed comparable number of primaries under lower and intermediate irrigation levels and these were lower than the number that developed under the highest irrigation level (Fig 3c). The highest irrigation level had the highest number of leaves while more leaves developed under lowest irrigation rate than under the intermediate levels.

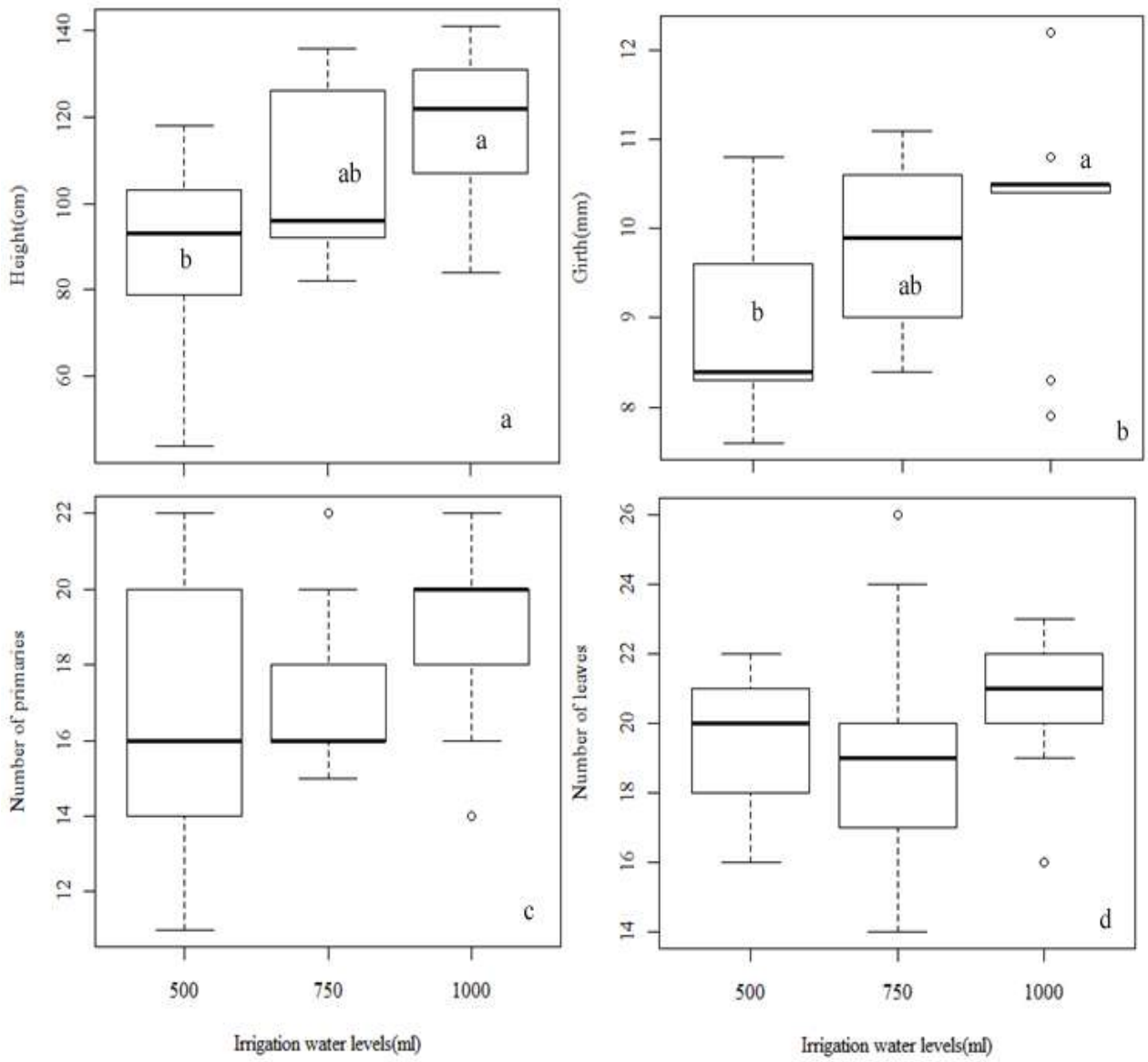

Figure 4: Growth response of young coffee to different irrigation levels

4.2.2 Effect of water levels on growth partitioning

There was no significant partitioning in growth of girth, number of primaries and height when coffee plants are irrigated with a high, medium and low amounts ($p>0.05$, Table 4). Growth partitioning was only significantly proportional between girth and number of primaries when coffee plants were provided with medium levels of irrigation ($r^2=0.45$, $p<0.05$, Table 4).

Table 4: Growth partitioning due to irrigation water levels

Treatment	Factors	r^2	*p*
1000ml	Primaries and height	0.057	0.5347
	Girth and primaries	0.034	0.6356
	Height and girth	0.285	0.1391
750ml	Primaries and height	0.044	0.5891
	Girth and primaries	0.449	0.0484*
	Height and girth	0.095	0.4194
500ml	Primaries and height	0.036	0.6082
	Girth and primaries	0.187	0.2448
	Height and girth	0.099	0.4086

4.3 Interaction between soil fertility options and water levels

The interaction between nutrient source and irrigation water level was only significant ($p<0.05$) in coffee height where the highest irrigation rate (1000ml) under inorganic fertilizer had the tallest coffee plants. The results indicate that coffee plants grow better under inorganic fertilizers when there is more irrigation water supply as shown by height, girth and number of primaries (Figure 5-7). However, more growth is achieved under low irrigation level when organic manure is used for soil fertility management (Figure 5-7). Taller plants and thicker stems of coffee plants were realized under organic manure while integrated fertility had more primaries and leaves than the inorganic and organic treatments.

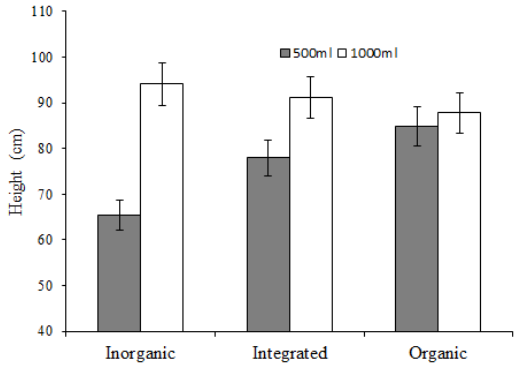

Figure 5: Coffee plant height under low and high water levels

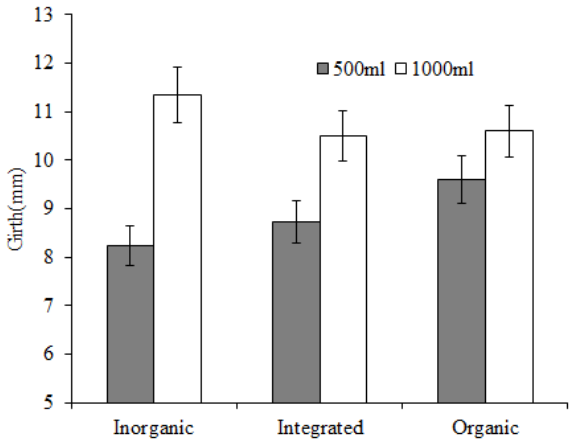

Figure 6: Coffee girth under low and high water levels

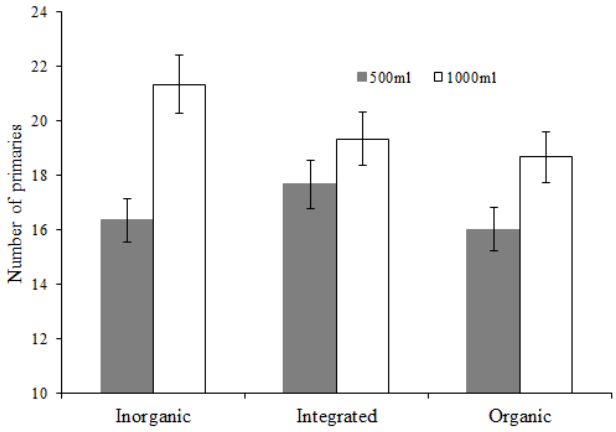

Figure 7: Number of primaries under low and high water levels

DISCUSSION

The readily available N from the inorganic fertilizer was fundamental in producing taller coffee plants than the organic manure which need time to decompose and produce the required nutrients. Thus, as the organic manure was decomposing, the plants were already benefiting from the inorganic fertilizers resulting in the taller coffee plants. The height benefits could not be translated into benefits on girth, as stem thickness, unlike apical growth, is promoted by availability of P

which tends to be more abundant in organic nutrient sources, making the organic treatment and the integrated fertility option as competitive as inorganic fertilizers (18).

Using organic manure and integrating it with inorganic fertilizer managed to produce a growth pattern (as measured through leaf and primary development) that is comparable to that of recommended levels of inorganic fertilizers. The competitive performance of integrated fertilizer to inorganic fertilizers was also reported by Nyalemegbe who concluded that combining poultry manure with inorganic fertilizers resulted in similar yields in rice as those obtained from using inorganic fertilizers alone. In addition, composted humus could add to other sources of organic soil nutrients that could be combined with inorganic fertilizers such as composted coffee pulp, cattle manure, poultry manure, sugarcane filter cake and crop residues (10; 12). Humus has the added advantage that it can be locally available from forest patches and this underlines the importance of managing trees on or around coffee farms for nutrient cycling and humus input (11; 22; 23).

Although the results showed that coffee grows more when applied with inorganic fertilizers, the growth partitioning showed that there is no balanced growth under this fertilizer regime. Organic manures had the most significant proportional growth indicating that the organic sources of nutrients are able to provide a balanced supply of nutrients. This is unlike inorganic fertilizers that supply only the nutrients in their formulation which may favour growth of some specific parts of the plant (2). For example, while the N may support growth of new leaves and height, P, which is the least of the proportion in the fertilizers used in this study, will be important for the development of the woody parts of the plants (3; 11). The balanced developments of both vegetative and woody parts of the plant as provided by organic manure are very important for plants such as coffee whose vegetative parts such as leaves are not harvested. It was surprising that there was no significant growth partitioning due to different levels of irrigation. It is expected that under water stress, the coffee plants will prioritize growth and maintenance of roots and other woody parts of the plant at the expense of vegetative growth of leaves and height (14; 15).

The less pronounced growth after the 26th week signifies the response of the coffee plant to abiotic factors particularly temperature during the winter months. The 26th week coincides with the start of winter in the study area and this indicates that although coffee is a perennial plant, plant growth is more pronounced and accelerated in the warm summer months than in cold winters. The coffee plant may also be changing priorities for nutrient allocation from primary growth to fruiting in winter, resulting in reduced vegetative growth. Logan & Biscoe (21) reported that the coffee plant continually makes new growth the whole year round but it is important to note that the vigour is reduced during winter months as indicated by the results. This reduced growth is apparent even in the absence of both soil fertility and water deficit and thus, it is important to make sure that the

coffee plant has adequate water and soil nutrients to avoid premature leaf senescence, dieback and other effects of water and nutrient shortages at the time when they are most required for supporting fruit development.

The coffee plant responds to increasing the amount of irrigation as indicated by the responses in girth and height. However, in terms of number of primaries and number of leaves, there were no significant responses to increasing water levels and this could be attributed to the fact that the coffee plant has inherent drought tolerance habits that enable it to survive and develop under low water levels. This is explained by Hess et al., (24) who observed that stoma of coffee are very sensitive to light and in sun-coffee systems, they close even in abundance of water.

Since the highest water supply level had the tallest and thickest stems, it shows that the young coffee plants significantly responds to increased irrigation. This reinforces the suggestion by Logan & Biscoe (21) that in coffee production, irrigation can be the deciding factor on success. It is however not clear from this study how the different water levels applied are related to crop requirements and actual water use efficiency. The water use of crops increases under increased water supply in as much as water loss through transpiration also increases(18).

The positive interaction between irrigation levels and organic sources on height and the improved growth perfomance of coffee plants under low water supply levels point to the importance of organic manure in regulating soil water for plant use. Ibrahim & El-Samad(18) also reported that water use significantly decreases with increasing amount of organic manure in the soil. The increased efficiency in growth of coffee plants under organic and integrated soil fertility under low irrigation could be due to the positive effects of organic manure on soil physical and chemical properties such as soil structure, texture, porosity and gradual nutrient release are significantly improved by addition of organic manure which resultantly improves the soil water holding capacity (2; 11). However, the availability of nutrients such as P and K from organic sources is significantly affected by availability of water in the soil and thus sufficient water should always be available for immobilising nutrients from organic sources (3; 18; 25).

CONCLUSIONS

The results indicated that organic and integrated nutrient sources are able to provide sufficient nutrients for healthy coffee growth. The use of integrated fertility management could be the most attractive option given that it reduces on both costs of inorganic fertilizers and also on quantities of composts required for efficient coffee growth. Higher levels of irrigation are required for promoting growth in coffee but exact crop water requirements for young coffee need to be established to avoid

oversupplying or undersupplying irrigation water. The use of organic manure improves the growth performance of young coffee under low water levels while application of inorganic fertilizers results in more growth at higher water levels. Further studies are required to determine if these trends are carried further to coffee yield and quality.

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A method to estimate maize yield in Zimbabwe using satellite remote sensing

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Abstract

In this study, we tested whether and at what time of the growing season we can use remotely sensed drought indices, particularly the Vegetation Condition Index-derived frequency of dry dekads to explain, as well as predict maize yield in Zimbabwe. We used regression analysis to relate in-situ maize yield estimated per ward to the number of remotely sensed dry dekads per ward based on the 2011 to 2012 and 2009 to 2010 growing seasons. Results indicate that although maize yield is a significant ($P<0.05$) function of remotely sensed dry dekads between October and December (OND), as well as, between January and March (JFM), the yield is mostly related to the dry dekads recorded in the OND period.

Key words: geo-information, remote sensing, satelite, maize yield.

INTRODUCTION

Increased frequency of drought spells in Zimbabwe(1,2) calls for the development of fast and less expensive crop assessment methods that give reliable crop performance information for the whole country. This information is relevant for decision makers to decide in advance on whether to import or export food. Conventionally, crop condition and yield assessments are done through sample-based field surveys that depend on several individual field staff (3).These surveys are often time consuming and costly. In this regard, the development of rapid and accurate methods to complement field surveys is critical.

The advent of satellite remote sensing has enabled the provision of spatial information at large spatial extents and at high frequency of observation (4). The use of remote sensing for crop monitoring has grown exponentially since the advent of the first Land Resource Satellite in 1972. For example, Kogan (5) applied remote sensing to estimate weather impacts on vegetation and Unganai and Kogan (6) estimated maize yield in Southern Africa using remote sensing data.

Among the major achievements in the use of remote sensing in agricultural monitoring is its ability to be combined with in-situ data to estimate crop yield (3,7,8).

Remote sensing provides an important added advantage to the use of traditional weather data such as rainfall measured at ground stations. This is because traditional weather data is available from sparsely distributed ground weather stations. The sparse distribution of weather stations limits crop assessment at local scales(9).

To date, several studies have demonstrated successful application of remote sensing in crop assessments (4,6,9,10,11) using different vegetation indices that include, the normalized difference vegetation index (NDVI),(11) vegetation condition index (VCI) (10)and temperature condition index (TCI)(10). Others used vegetation health index (VHI) which is a combination of VCI and TCI (10,12). Many of these studies focused on testing for correlation between crop yield and satellite based vegetation indices. However, less focus has been paid to prediction. Moreover, previous studies have used aggregated data at district level thereby generalizing information over large geographical areas. Thus, the development of predictive models using less aggregated data is critical.

While factors such as crop management system, crop variety, pests, mechanization and soil fertility may vary little over the years, the most important factor for maize yield is soil moisture content during the growing season(13,14,15).The severity of the effect of dry spell occurrence on maize yield is dependent on the crop phenological stage at which the dry spell occurred. For example, Khodarahmpour and Hamidi (16) showed that dry spell occurrence at vegetative, flowering and yield formation stages reduce maize yield by 15, 40 and 60% respectively when compared with optimal growth conditions. Other studies indicate that the flowering stage is the most sensitive stage to water stress (17). Therefore greatest reduction in maize yield occurs if the flowering and/or yield formation stages coincide with occurrence of dry spells.

In this study, we tested whether and at what time of the growing season, we can use remotely sensed drought indices, particularly, the Vegetation Condition Index-derived frequency of dry dekads to explain, as well as predict maize yield in Zimbabwe.

METHODOLOGY

Study area

The study area covers Zimbabwe's cultivated areas.

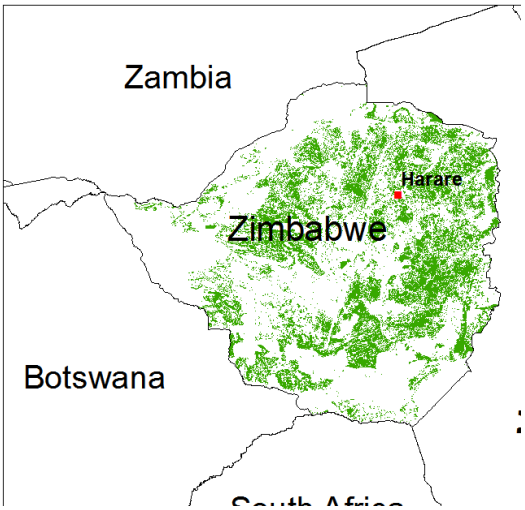
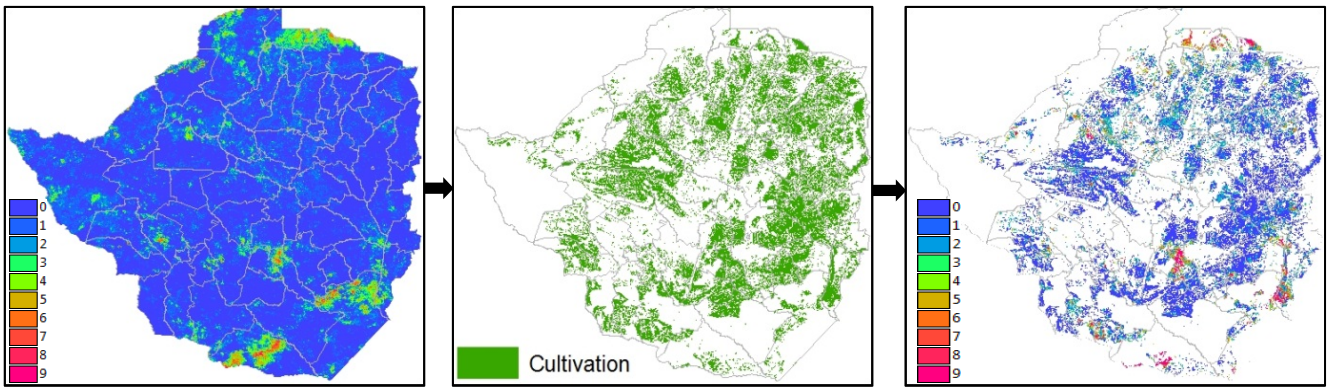


Fig. 1: Study Area

Data



Sum of Dry dekads | Land-cover Mask | Sum of Dry dekads for cultivated area

Fig. 2: Masking of non-cultivated areas using the land-cover map

The data used in this study are based on long-term, dekadal SPOT VGT Normalized Difference Vegetation Index (NDVI).This dataset consists of 10-day maximum NDVI value composites at 1.1 km spatial resolution. We used SPOT VGT data from October 1998 to April 2012 for Zimbabwe.

In-situ data was summarized according to the administrative (ward) boundaries from the Surveyor General's Office. The ward boundaries were also used for zonal statistics on the remote sensing data. The cultivation mask was derived from the Global land-Cover Facility (GLCF, 2006). The effects of land cover changes that might have occurred between the date of the land cover map and the study period were deemed insignificant to the study. In-situ crop yield data was obtained from the Ministry of Agriculture, Mechanization and Irrigation Development (MAMID). This data is

collected through sample-based field surveys at ward level and is the most reliable in-situ maize yield data in Zimbabwe.

We calculated the vegetation condition index (VCI) for the 2011 to 2012 and 2009 to 2010 growing seasons using long-term SPOT NDVI data from 1998 to 2012. VCI values range from 0% for extremely unfavorable vegetation conditions to 100% for optimal conditions. VCI is calculated as indicated in equation 1.

$$\mathrm{VCI} = \frac{\mathrm{NDVIi} - \mathrm{NDVImin}}{\mathrm{NDVImax} - \mathrm{NDVImin}} * 100\% \qquad 1$$

where: *NDVIi* is the dekedal *NDVI*, *NDVImax* and *NDVImin* are the absolute long-term maximum and minimum NDVI respectively calculated for each pixel and dekad from multi-year NDVI data, *i* defines the dekad.

We used a VCI threshold value of 35% to define a dry dekad(18) (ten day period) whereby all dekads with a VCI of less than 35% are considered dry. The seasons were split into two parts; that is October to December (OND) and January to March (JFM). Then we calculated the sum of all dry dekads per pixel for each part of the season for the two seasons 2011 to 2012 and 2009 to 2010. The agricultural mask was applied to the dry dekads map so that we exclude non-agricultural areas from analyses (Fig.2). We also masked out irrigation schemes from the analysis to focus on rain-fed agriculture only. We calculated spatially defined median number of dry dekads per ward weighted by the number of pixels in that ward.

Average yield of all wards with the same median number of dry dekads was calculated and using non-linear regression analysis we related the number of dry dekads to the corresponding maize yield. We repeated this analysisfor each part of the growing season.

RESULTS

Figure 3 illustrates that there is a significant ($P<0.01$) relationship between the number of dry dekads and average maize yield for the OND part of 2011 to 2012 growing season. We observe that the dry dekads occurring between October and December explain 94% of variance in maize yield for this season. The relationship is defined by a logistic function.

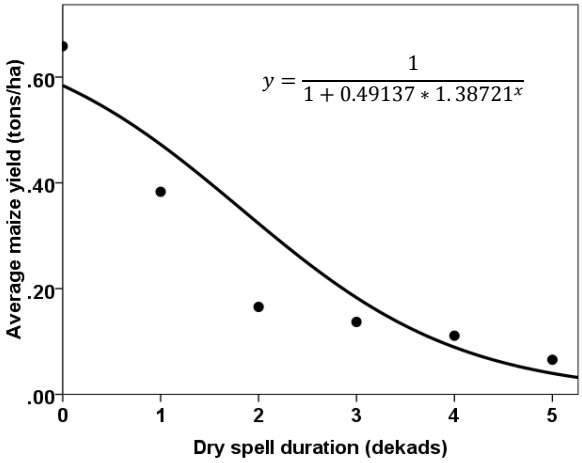


Fig. 3: Regression of number of dry dekads and average maize yield for the OND part of 2011 to 2012 growing season.

Figure 4 demonstrates a significant (P < 0.01) relationship between the number of dry dekads and average maize yield for the JFM part of 2011 to 2012 growing season. We observe that 81% of variation in yield is explained by frequency of dry dekads between January and February which is 13% lower than the variation explained by dry dekads between October and December of the same season.

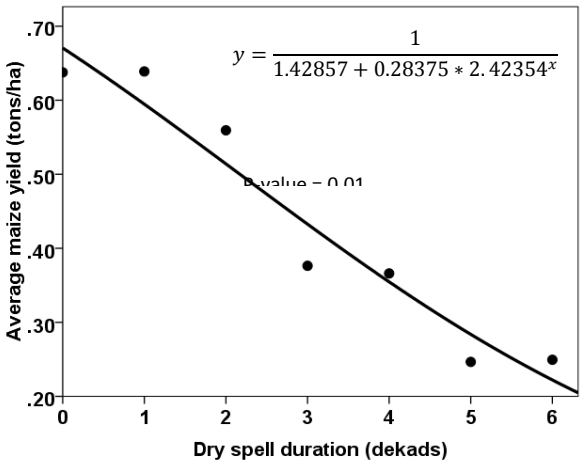


Fig. 4: Regression of number of dry dekads and maize yield for the JFM part of 2011 to 2012 growing season.

Figure 5demonstrates a significant (P<0.01) relationship between the number of dry dekads for October to December and average maize yield for the 2009 to 2010 growing season. For this season we observe that dry dekads that occurred from October to December explain 97% of the variance in maize yield.

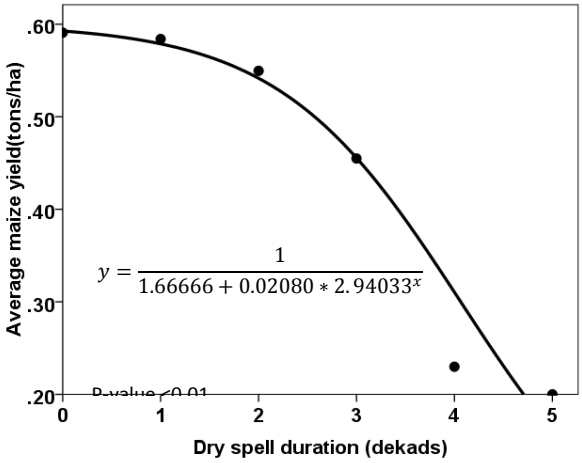


Fig. 5: Regression of number of dry dekads and maize yield for the OND part of 2009 to 2010 growing season.

Figure 6 illustrates that there is a significant (P=0.02) relationship between the number of dry dekads and average maize yield for the JFM part of the 2009 to 2010 growing season. 68% of the variation in maize yield is explained by frequency of dry dekads between January and February. The relationships between the dry dekads and maize yield are defined by a logistic function.

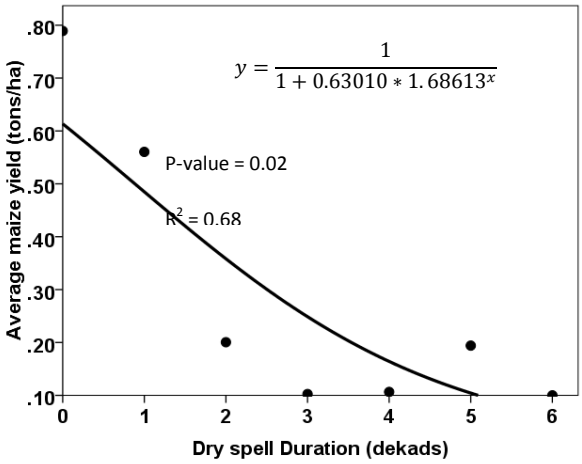


Fig. 6: Regression for number of dry dekads and average maize yield for the JFM part of the 2009 to 2010 growing season.

DISCUSSION

Results for the 2011 to 2012 and 2009 to 2010 growing seasons show a consistent relationship between the frequency of dry dekads and average maize yield for the two seasons. While occurrence of dry dekads in both parts of the growing season has great impact on the average maize yield, occurrence of dry dekads from October to December has a higher impact on maize yield than occurrence between January and March for the two seasons assessed. These results are supported by

a study in Ethiopia which also showed that grain yield is significantly reduced by occurrence of dry spells especially before the tasseling stage(19). Maize crop is more sensitive to dry spells at reproductive stage than any other part of the growing season(17).This study shows that maize yield is more responsive to dry spells in OND than in JFM, however it was expected that influence dry spells would be higher in the second half of the season than the first half since rain-fed maize crop reaches critical stage between December and February depending on the start of the season in a particular area. Delineating the country by start of season would help to produce results consistent with literature. Also dividing the season into smaller time intervals would give a more precise critical period.

The NDVI from which we calculate VCI is dependent on rainfall (20,21). Thus, the number of dry dekads derived from a rainfall dependent index (VCI) suggests that soil moisture may be a major contributing factor to crop yield. This is not surprising since moisture is a major limiting factor in rain-fed agricultural systems.

While there is a significant relationship between VCI based dry spells and yield there may also be other factors such as crop management and crop variety that may affect crop yield. However in this study we focused on the relationship between remote sensing derived frequency of dry dekads and in-situ crop yield. Even though the vegetation condition in a cropped field is highly dependent on rainfall, and thus we coined the word “dry dekad” on the premise that soil moisture is the major limiting factor to crop yield, the VCI already incorporates all other factors influencing crop condition and thus crop yield.(22). VCI is a more direct measure of the crop condition than soil moisture because it is derived from crop reflectance.

CONCLUSION

In this study we conclude that remotely sensed drought indices, particularly, the Vegetation Condition Index-derived frequency of dry dekads can explain, as well as predict maize yield in Zimbabwe.

RECOMMENDATIONS

We would recommend that follow up studies be done on the application of remote sensing for crop monitoring especially with higher resolution imagery and incorporating other factors

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Investigating the potential use of water hyacinth (Eichhornia crassipes) for biogas and organic fertiliser production

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Abstract

Different fermentation conditions were investigated for their effects on the biogas yield from water hyacinth (*Eichhornia crassipes*). The study was conducted over a period of 45 days using batch fed anaerobic digesters. A water hyacinth to water ratio of 1:4 exhibited maximal biogas production and the highest amount of biogas with an average methane content of 58% was generated in the temperature range 31°C to 40°C. Co-digestion of water hyacinth with cow dung at a ratio of 3:1 respectively was shown to improve the yield of biogas and methane content (72% of the total biogas produced). The obtained digestion slurry had higher nitrogen (1.91%), phosphorus (2.22%) and potassium levels (2.84%) compared to organic fertilisers such as dung manure commonly used by small scale farmers in Zimbabwe. There is a need to raise awareness on the potential application of water hyacinths as cheap sources of high quality biogas and organic fertiliser.

Key words: water hyacinth, biogas, organic fertiliser

INTRODUCTION

Water hyacinths (*Eichhornia crassipes)* is an invasive aquatic plant that is native to the Amazon basin and its presence in Zimbabwe was first recorded in the Mukuvisi and Manyame (formerly Hunyani) rivers in 1937 (1). The plant due to its high growth rate (and lack of a natural predator in Zimbabwe) subsequently became a serious pest in the major water bodies of Zimbabwe and by the late 1980s it had infested Lake Kariba, Lake Mutirikwi and Lake Chivero (1). Chemical control, physical/mechanical control and biological control methods have been employed in Zimbabwe to control the weed with varying levels of success. Biological control of the water hyacinth has been effective in Zimbabwe as shown by the reduction in weed coverage in Lake Chivero from an

estimated 35% in the late 1980s to 3% by the late 1990s after the introduction of the weevil *Neochetinaeichhorniae* as a biocontrol agent (2). The economic challenges and resultant breakdown in infrastructure faced by Zimbabwe in the lost decade (2000-2010) negatively affected the progress that had been made in controlling water hyacinth (and other alien plant species) and according to the Environmental Management Agency (EMA), water hyacinth is now a common feature characteristic of water bodies in Mashonaland (3). It is estimated that the Government of Zimbabwe needs over US$50 million annually to control water hyacinth and other alien plant species (3). Experts in the area of water hyacinth research believe that it is difficult to eradicate the water hyacinth as the conditions that allow it to proliferate are difficult to control (4).

Biomass is biological material obtained from living or recently living plant matter that can be processed into energy (electricity, fuel and heat) and it accounts for 61% of the energy used in Zimbabwe (5)(6). Fuel wood is the most important domestic fuel in the country as it is a major source of energy for over 80% of the rural and peri urban population (7). The excessive dependency on fuel wood has resulted in environmental degradation and there is a need to find alternative sources of energy which are renewable and friendly to the environment (6).

Eichhornia crassipes is an excellent source of biomass due to its high biomass growth rate (up to 17 tonnes per hectare per day) (8)(9) and in countries such as India, Nepal Bangladesh; it has shown potential as a source of renewable energy in the form of biogas (10). Biogas is a combustible mixture of methane (50 -70%) and carbon dioxide with traces of hydrogen sulphide and water. Biogas is formed naturally from the anaerobic bacterial decomposition of organic matter and in the process gives organic fertiliser as a secondary by-product (11)(12). The anaerobic decomposition of organic matter occurs in four phases (hydrolysis; acidogenesis; acetogenesis and methanogenesis).

The biomass conversion efficiency of water hyacinth to biogas has been shown to be around 38% (13) (14). Numerous studies to improve the biomass conversion efficiency and biogas yield from water hyacinth have been conducted worldwide (15). The high suitability for the use of water hyacinth as an organic fertilizer may be attributed to its low and narrow margin carbon: nitrogen ratio (C:N) of 1:25 and low lignin content of only 9% compared to other plant materials (such as wheat straw) commonly used for mulching and preparing composts (16). There are commercially available organic fertilisers (such as Ecogreen manufactured by Soamso Ltd, Equador) that are derived from the aerobic decomposition of water hyacinth (17). There are several nutrient content values cited in literature for liquid organic fertilisers derived from water hyacinth. The cited nitrogen levels range from 1.9 – 4%, the phosphorus levels range from 1 – 2.9%, and the potassium levels range from 2.9 – 3.3% (17) (18) (19). However, in Zimbabwe, limited research has been

conducted on the potential application of water hyacinth for biogas and concurrent organic fertiliser production.

The goal of this study was to investigate the potential use of water hyacinth for biogas and concurrent organic fertiliser production in Zimbabwe.

OBJECTIVES

The objectives of the study were to determine the water hyacinth optimum biogas production conditions (for selected parameters) and evaluate the composition of the digestion slurry for use as an organic fertiliser.

MATERIALS AND METHODS

Sample Collection and Preparation

Water hyacinth used for the study was obtained from the sewage stabilisation ponds (at the Scientific and Industrial Research and Development Centre in Hatcliffe, Harare Zimbabwe). The cow dung was collected from the SIRDC cattle pen. The water hyacinth was hand-pulled from the source and put into polyethylene bags which were tied up to avoid wilting of the plants. The plants were rinsed under running water upon arrival in the laboratory to remove external contaminants and were then chopped into small pieces.

Biomethanation unit

The biomethanation unit consisted of 5 litre polyethylene containers (anaerobic digesters) which were sealed by a two way rubber stopper and connected by a gas pipe through one of the stoppers to a measuring cylinder. In order to prevent the dissolution of biogas in the water, an acified brine solution was prepared by adding sodium chloride to water until a supersaturated solution was formed. Little drops of sulphuric acid were added to acidify the brine solution. A series of batch-fed reactors were placed together for studying the biogas production under varying conditions. The biogas evolved was measured using the water displacement method (20).

Sample analysis

pH analysis: pH was measured using a pH meter (Knick 766 Calimatic) which was calibrated and operated according to the manufacturers' specifications.

Temperature analysis: temperature was measured using a bulb thermometer (0-100°C).

Biogas analysis: the biogas gas composition analysis was done using a Geotech portable biogas analyser.

Digestion slurry analysis: Nitrogen (N_2) composition was determined using the Kjeldahl method; Potassium (K) composition was determined using atomic absorption spectroscopy (AAS – GBC); Phosphorus (P) was determined using the UV/VIS spectrophotometer (Shimadzu)

The negative control for all the parameters tested was a digester that only contained water and no substrate.

Effect of water hyacinth dilution (ratio of water hyacinth to water) on biomethanation

The effect of dilution on biomethanation was tested at water hyacinth: water ratios of 1:1, 1:3, 1:4, 1:5 and 1:6. The digesters with the different ratios were set up in duplicate and the incubation period was 40 days. The temperature and the pH in the digesters were measured after every 3 days and the volume of biogas produced was measured after every 24-48hours. This study was conducted at room temperature.

Effect of temperature on biomethanation

This was evaluated in the temperature range $10^{O}C$ to $55^{O}C$ at a water hyacinth: water ratio of 1:4. The digesters at the different temperatures ($5^{O}C$ intervals) were set up in duplicate and the incubation period was 40 days. The biogas composition was analysed after every 5 days.

Effect of co-digestion of with cow dung on biomethanation

The effect of co-digestion with cow dung was investigated at water hyacinth: cow dung ratios of 1:1, 1:3, and 3:1 respectively. The digesters were set up in duplicate and incubated in the temperature range $31\text{-}41^{O}C$ for 45 days. The temperature and the pH in the digesters were measured after every 3 days and the volume of biogas produced was measured after every 24-48 hours. The biogas composition was analysed after every 5 days.

Nutrient analysis of the digestion slurry

Samples of 40 days digestion slurry were collected and filtered and centrifuged at 10,000 rpm for 15 minutes. The resulting supernatant was then taken for nutrient analysis.

Data analysis

The data was analysed using the Data Analysis ToolPak (Microsoft Corporation, 2010). Statistical analysis of variance was carried out using one-way ANOVA with the alpha value of 0.05.

RESULTS

Effect of water hyacinth dilution

The dilution ratio of 1:4 produced the highest amount of gas over the 40 day incubation period. Water hyacinth dilution had no significant effect on temperature and pH within the digesters.

Table 5: Mean amount of biogas produced per dilution ratio in 40 days

Dilution Ratio	Average biogas yield (ml/100g)*
1:1	113 ± 0.5
1:3	827± 7
1:4	1253± 2
1:5	833± 6
1:6	804± 3.5

The total amount of biogas produced per 100g of substrate was significantly different between the different dilution ratios ($p<0.05$) hence diluting water hyacinth has a significant effect on biogas production.

Effect of temperature on biomethanation

Incubation temperature had an effect on both the biogas production and methane content of the generated biogas. The highest volume of biogas was produced in the incubation temperature range of 36-40°C. The highest methane content by percentage of the biogas was recorded in the temperature range 10-15°C (68%). However, the highest amount of methane by volume was produced in the incubation temperature range of 31-40°C. Increasing the incubation temperatures had an effect of decreasing the methane content of the generated biogas.

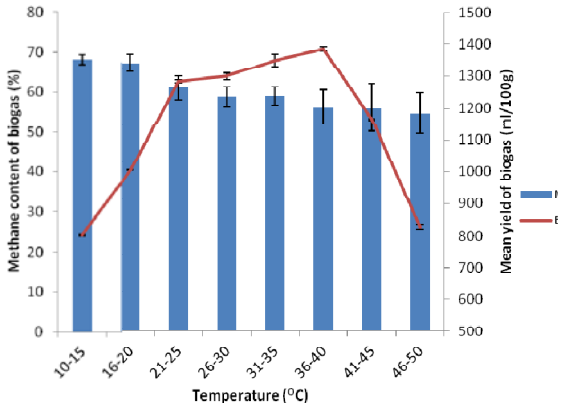

Figure 1: Effects of temperature on biomethanation

Low (10-15°C) and high (46 - 55°C) incubation temperatures resulted in the generation of the least amount of biogas.

Effect of co-digestion of with cow dung on biomethanation

The mixing ratio of cow dung to water hyacinth had an effect on the total biogas production ($p<0.05$).

Table 6: Gas production and methane content at different water hyacinth to cow dung ratios

Substrate mixing ratios (water hyacinth: cow dung)	Gas production (ml/100g)	Methane content (%)
1:1	1583±7	65
1:3	1377±1	68
3:1	1442±5	72

The highest methane content was observed in the water hyacinth: cow dung ratio of 3:1 and co-digestion had no significant effect on the digester temperatures. All the digesters operated at a pH range between 6.3 and 6.8.

Nutrient analysis of the digestion slurry

These values are a composite of the digestion slurry obtained from the bioreactors used in the study.

Table 7: Nitrogen, Phosphorus and Potassium content of digestion slurry

Nutrient	Average content (%)
Nitrogen	1.91±0.02
Phosphorus	2.22±0.21
Potassium	2.84±0.13

DISCUSSION

The first experiment was set up to determine the optimum water hyacinth to water ratio which would allow efficient mixing of substrate and micro-organisms and subsequently result in optimum biogas production (21). The average biogas produced between the different dilution ratios was significantly different ($p<0.05$) and the dilution ratio of 1:4 (water hyacinth: water) resulting in the generation of the highest amount of biogas. This implies that at this ratio there was efficient mixing of the substrate and micro-organisms. Lower dilution ratios generated lower volumes of biogas due to limited movement and growth of bacteria due to reduced water volume. This resulted in limited mixing of the substrate and micro-organisms and hence the reduced biogas output. Higher dilution rates resulted in diminished biogas output as the substrate quantity became the limiting factor. The optimum dilution ratio of 1:4 obtained in this study is consistent with the observations by Jagadish *et al.* in a study that was published in 2011 (22). In their study Jagadish *et al.* (2011) observed that fermentation slurry of water hyacinth to water in the ration 1:4 resulted in the production of maximum biogas yield. The negligible digester temperature differences show that dilution ratios have no effect on digester temperature. The observed pH in the different digesters (with different dilution ratios) ranged from 5.8 to 8.1 during the course of the study. This range is ideal for biogas production as it provides an ideal environment for hydrolysis and oxidation bacteria (optimum pH range of 4.5 to 6.3) and the methane and acetic acid formation bacteria (optimum pH range of 6.8 to 8.1). This suggests that pH and temperature did not have an effect on the biogas output from the different digesters.

Biomethanation is dependent on the temperature at which the anaerobic digestion occurs as it significantly affects the conversion, kinetics, stability and methane yield and quality (23). This explains why it was chosen as one of the parameters that we were going to investigate in our study. In our study, the effect of temperature on biogas yield and methane content was significant. There was a general increase in biogas yield from $10^{O}C$ to $40^{O}C$. The highest biogas yield was recorded in the temperature range $36^{O}C$ to $40^{O}C$ followed by the temperature range $31^{O}C$ to $35^{O}C$. However,

ANOVA comparison between the two incubation ranges indicated that there was no significant differences in the yield ($p>0.05$). This implies that the optimum temperature range for biogas production observed in our study was $31^{O}C$ to $40^{O}C$. This implies that the majority of the methanogens are mesophilic and is consistent with what other researchers have observed (24) and used (4)(25) in their studies. The methane content in the generated biogas decreased with an increase in the incubation temperatures. This is also consistent with observations by other researchers (26) whose results have shown that low digestion temperatures give rise to a reduced yield of biogas that has high methane content. Several explanations have been put forward to try and explain this phenomenon (26) (27)(28) (29). The explanations put forward to explain this phenomenon include: additional production of acetate from homeoacetogens (at the lower temperatures) and methane production due to the activity of psychrophilic methanogens.

Co-digestion of water hyacinth with cow dung at a ratio of 3:1 respectively was shown to improve the yield of biogas and methane content (72% of the total biogas produced). This tallies with results that have obtained in other studies in which methane yield has been shown to be enhanced by co-digestion of water hyacinth with cow dung (30) (31) (32). Co-digestion improves the digestibility of the substrate through availing additional nutrients to the microbes and the cow dung provides essential microbes (water hyacinth lacks anaerobic bacteria) which enhance the rate limiting hydrolysis process (30) (31).

The nitrogen (N_2), phosphorus (P) and potassium (K) values obtained in our study from the analysis of the liquid digestion slurry are much higher than the values for the organic fertilisers commonly used by small scale farmers in Zimbabwe.

Table 8: Nutrient quality of solid organic fertilisers commonly used by small scale farmers in Zimbabwe*

Fertiliser type	N_2 (%)	P (%)	K (%)
Cattle manure	1.50	0.15	0.78
Leaf litter	1.40	-	-
Anthill soil	0.23	0.05	-
Compost	0.34	0.12	-
Crop residue	0.45	0.06	-
Legumes	1.50	0.08	-
Water hyacinth digestion slurry	**1.91**	**2.22**	**2.84**

*Adapted from (18)

The obtained N_2, P, K values also fall within the range of values cited in literature for organic fertilisers derived from water hyacinth (17) (18) (19).

CONCLUSIONS

Water hyacinths are potentially cheap sources of high quality biogas and organic fertiliser in Zimbabwe.

RECOMMENDATIONS

There is a need to raise awareness amongst different stakeholders on the potential application of water hyacinths as cheap sources of high quality biogas and organic fertiliser.

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SECTION II:

ENVIRONMENTAL SCIENCES

Soil erosion and its Effects on Arable Land and River Systems of Zimbabwe. Is this a Catchment Management issue? A Look Beyond the Fast Track Land Reform Program.

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ABSTRACT

This study determined the effects of soil erosion on arable lands and river systems and how this related to catchment management. This work was done in Mashonaland East and Central provinces of Zimbabwe in 2011. It was part of a national Soil and Water Conservation baseline survey. Within each province, districts were randomly selected based on the presence of breached earth dams and eroded arable lands. In these districts, there were farmers settled under fast track land redistribution program as well as those under traditional land holding. Results showed that 67% of arable lands were not protected and as such the fields were eroded. 99% of the breached dams were as a result of poor designs, wrong construction of earth embankments or poor dam maintenance. Sedimentation within several dams (breached or not) visited was evident. This was indicated by presence of plant species like reeds on the spillway mouth. There is need, therefore, for government policies to focus more on promoting proper catchment area management. There is also need for government through its relevant ministries to enforce proper earth dam construction and maintenance which must be done according to laid out principles recognised by government.

Key Words: soil erosion, catchment, arable, sedimentation, land.

INTRODUCTION

The existence of human beings on earth depends completely on the availability of critical resources, such as land, water and foodstuffs. These key assets are derived from the natural environment (Maposa, Hlongwana, & Muguti, 2010). Without this natural environment, there can be neither society nor economy (Doyle & McEachern, 1998).The proper and sustainable utilisation and management of this essential resource can go a long way in sustaining life on mother earth. However, improper and unsustainable utilization of land can result in soil erosion which if left unchecked leads to desertification and the siltation of river systems. Soil erosion is mostly

manifested as gullies that render large tracts of land virtually unusable, threatening water supply and quality (Booth, McCullum, Mpinga & Mukute, 1994). In order to curb this problem of soil erosion and its resultant effects, proper catchment management must be implemented.

The aim of this paper is to emphasize the importance of catchment management. According to Australia's National Committee on Water Engineering (NCWE, 2010). Integrated Catchment Management (ICM) improves and integrates the management of land, water and related biological resources for sustainable and balanced use. The principle of ICM is that the process should involve the whole community in developing the strategic approach to integrated resource use (NCWE, 2010). A catchment is the area from which the rainfall drains into the watercourses through surface runoff. In a catchment, much of the surface is land and a smaller portion consists of the river channel. Poor farming systems resulting in soil erosion will eventually result in reduced capacity of river systems.

Water erosion by definition is a process in which soil is detached and transported from the land by the action of rainfall, runoff, seepage and/or ice. Sheet, rill, gully, streambank and tunnel erosion are terms used to describe commonly occurring types of water erosion (Houghton and Charman 1986). Soil erosion is now regarded as the world's most immediate and urgent problem, especially in the developing countries (Maposa et al, 2010). Some scholars have estimated that about 35% of the earth's surface is threatened by soil erosion (Dalelo, 2001).Soil erosion was also found to have a direct correlation with population density (Whitlow, 1987). Population increase, poverty and overgrazing are often cited as major causes of degradation particularly in sub-Saharan Africa (Booth et al, 1994).

Soil erosion studies in Zimbabwe have indicated estimated annual soil loss due to sheet erosion to be as much as 50 tonnes/ha (Elwell, 1987). It was also shown that there is more soil loss per unit area per year (8.14 t/ha/year) using the conventional methods of farming as compared to mulch ripping under zero tillage (1.83 t/ha/year) (Smith, 1988). Whitlow and Campbell (1989) estimated that 25 per cent of the communal areas were severely eroded compared to 2 per cent in the commercial areas. Whitlow (1987) found that soil erosion was prevalent in all agro ecological zones, but more pronounced in zones III, IV and V. Zones IV and V are characterized by unreliable rainfall and poor soils. This conclusion can be justified by the enactment of the Land Apportionment Act (LAA) of 1930. The LAA resulted in an uneven and unfair distribution of arable land resulting in the minority white settlers (a population of less than 50,000) occupying

51% of arable land whereas the majority African peasants (a population of about 1,081,000) occupying only 22% (Moyana, 2002). These were situated in newly established native reserves.

The area given to the Africans was marginalised as well as too small to sustain the population thus resulting in over exploitation of the natural resources and consequently soil erosion. Yields significantly went down thus forcing the Africans to seek for employment in towns, mines or commercial farms for subsistence. The LAA and its effects did a lot to push the African to take up arms against this gross injustice. This in principle is what led the country to the second chimurenga war as well as the Fast Track Land Reform Program (FTLRP) 'third chimurenga' of 2000. This paper focused on the effects FTLRP had on the environment over the past decade of 2000 to 2010. In particular it focused on erosion in arable lands, siltation and breaching of small earth dams. It tried to prove the point that poor land management at farm level can result in soil loss of arable land and siltation of dams.

OBJECTIVES

This study sought to determine the effects of catchment area management on arable lands and river systems. Specifically, it:

- Assessed the level of soil erosion and related it to catchment area management.
- Investigated the prevalence of river siltation and related it to catchment area management.

METHODOLOGY

The study was a baseline survey; hence the methodology employed was meant to give a general indication of what is transpiring in the provinces in the post land reform era.

Study area

The study was conducted in Mashonaland East and Central provinces of Zimbabwe (Fig.1). For Mashonaland East province the districts selected were: Chikomba, Marondera, Goromonzi, Murewa, Mutoko and Seke. Mazowe, Guruve, Muzarabani, Rushinga, Mt Darwin, Shamva and Bindura were selected from Mashonaland Central province.

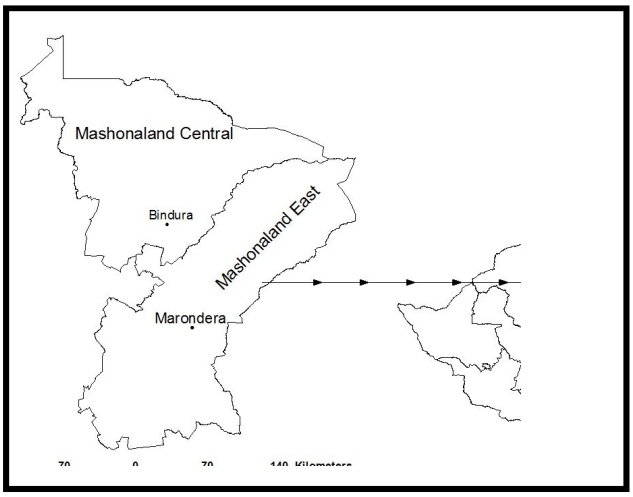

Figure 1: **Mashonaland East and Central Provinces of Zimbabwe**

The districts selected range from region II to IV whose rainfall pattern ranges from less than 650mm/annum for region IV to between 750-1000 for regions IIa and b. (Vincent and Thomas, 1960). Soils are generally of the kaolinitic order, with patches of the amorphic and natric orders also existing in Mashonaland Central province. The vegetation in the study area is mainly miombo woodlands with small portions of dry savanna (Whitlow, 1987).

Data collection

Preliminary and secondary Data

For each province and district visited, the research team included the Chief engineer responsible for Soil and Water conservation issues at national level, his engineer, the provincial head from the department of Mechanisation, his district head and technician responsible for soil and water conservation issues. Rapid and detailed assessments of physical condition of fields, gullies and dams (breached or not) were done. Five days were allocated for each province. These assessments were visual and involved observing activities done within catchment areas and the land management practices in use. Nine arable lands and fourteen dams were visited during the study.

Of nine the arable lands, seven were A2 farms, one was A1 and one large scale commercial. This, however, was rather too small a sample if we would consider the total number of allocated A1 and A2 farms for the two provinces which was estimated at 1295(PLRC,2003). Data collected were analysed in a spreadsheet (microsoft excel). Secondary data was obtained from electronic journals and reports.

Factors that influence soil erosion and their weighting

Arable land

Absence of infield conservation works to help de-concentrate flood water normally results in soil loss. The following are factors that this study has concluded to be greatly responsible for influencing soil erosion. These are presence or absence of conservation works done according to set standards derived from Elwell (1981) and tillage system in use. Conservation works were classified according to whether or not they existed. Conformity to standards of conservation works was classified according to whether or not there was adherence to set standards as specified by Elwell (1981). Tillage systems were also classified according to whether it was conventional or no till. Table 1 shows the contribution of each tillage system.

Table 1: Classification of standard conservation works, tillage system and weighting for arable lands

	Classification and weighting (%)	
Std Conservation works	Present (5%)	Absent (95%)
Tillage system	No till (20%)	Conventional. (80%)

For standard conservation works, classification of present was allocated a weight of 5% as it assumed to be very minimal. Classification of absent was allocated a weight of 95% as it is assumed to be very high. No till and conventional were allocated 20% and 80 % weights respectively. Type of erosion was also classified and weighted as sheet (20%), Rill (30%), Gully (50%).

Earth Dams

Dam breaching and poorly designed spillways are the main causes of massive soil erosion. Dam breaching usually leads to gully formation, siltation of river systems and loss of aquatic and / or human and animal lives. The bigger the capacity of a dam, the greater the land damage after the dam has failed. Dam capacity can be estimated from the following relationship:

$$Q = \frac{LTD}{6} \qquad (1)$$

Where Q =Capacity (m^3)

L=Length of embankment (m) at full supply level.

T = Throwback (m).

D = Maximum water depth (m)

(Shaw, 1977)

However, for simplification purposes, this study used the estimated dam height to classify the dams according to whether it was small, medium or large. This was taken from the definition by the Ministry of Water which defines a small dam as a structure which has a vertical height of less than 8m measured from the non-overflow crest of the wall to the lowest point on the downstream face of such wall or is capable of storing less than 1million m^3 of water at full supply level (Muyambo, 2000). The first part of this definition was used. Their weightings were as follows: Small (10%), Medium (20%) and Large (70%). This was done through estimating by observation, the maximum water depth as observed at the embankment. Table 2 shows the classification and weighting of contribution to soil erosion for different dam size classifications. It was created from observations so that it would be easy to classify the dams. Each of the classification was given a weighting to show its relative contribution to soil erosion.

Table 2: Vertical height parameter (D) used to estimate dam capacity and their classification and weighting according to their relative contribution to soil erosion for the different dam sizes

Classification	D(m)	Contribution to soil erosion weighting (%)
Small	≤ 8	10
Medium	8≤D≤15	20
Large	≥15	70

The return slope was rated as follows:

Signs of siltation in each dam (breached or not) were also noted. A good sign of the presence of siltation is the presence of plant growth at the spillway mouth. This is because subcritical flows exist in the inlet channel of spillway thus allowing deposition of sediments. The next thing was on spillways. There are several types of spillways. However, this study only dealt with dams that had either a cut spillway or a natural spillway. These were treated as similar though in reality they are not.

Poorly designed spillways usually result in gully formations on the spillway channel. They are supposed to be firm and able to withstand the erosive force of flood waters as they flow through the spillway channel.Subcritical flow exists in the inlet channel and the flow is usually supercritical in the exit channel. A spillway channel is also supposed to include a training bank to help channel flood waters back to the river channel without eroding the downstream toe of the earthen dam wall. The spillway's contribution to degradation (water erosion risk rating and scoring) was calculated after the methodology by Wells (1988, pp 8-14) (See table 5). Only the water erosion risk rates were scored. This method used the slope of the exit channel of spillway (return slope) (See table 3) and the erodibility of the channel floor (based on soil resistance to detachment) (See table 4). For breached dams, spillway channel slope will be replaced by the slope of the new channel or gully formed after breaching of dam.

The erodibility of the spillway channel was rated as follows:

Table 4: Rating of soil erodibility

SURFACE TEXTURE GROUP	SURFACE RIPRAP/TURF	SOIL RESISTANCE	ERODIBILITY RATING
Sands-Sandy loams	Nil-few	Low-Moderate	High
	Common-more	Moderate	Moderate
Sandy loams-loams	Nil-few	Low-Moderate	High
	Common-more	Moderate	Moderate
Loams-clay loams	Nil-few	Moderate	Moderate
	Common-more	High	Low
Clay loams-medium heavy clays	Nil-few	High	Low
	Common-more	Low	High

Water erosion risk rating was classified as follows:

Table 5: **Water erosion risk classification and weighting**

	SLOPE CLASS (FROM TABLE 3)	SOIL ERODIBILITY CLASSIFICATION AND RATING (FROM TABLE 4)	WATER EROSION RATING AND SCORING (%)
1	0-3(Level-very gentle)	High	Very low (1)
		Moderate	Very low (1)
		Low	Low (4)
2	3-10 (Gentle)	High	Low (4)
		Moderate	Moderate (10)
		Low	Moderate (10)
3	10-20 (Moderately inclined)	High	Low (4)
		Moderate	Moderate (10)
		Low	High (25)
4	20-30 (Moderately	High	Moderate (10)

RESULTS

Rapid and detailed assessments

Arable lands

Thirty three percent (33%) of the assessed arable lands had conservation works in place (See figure 2). Sixty seven percent (67%) of the assessed arable lands were found either without conservation works at all or with conservation works not constructed according to set standards. These arable lands showed advanced sheet and gully erosion in action as shown in figures 3 and 4.

Table 4: Arable land and type, standard conservation works, tillage systems, form of erosion active and weighted contribution to soil erosion in the nine arable lands

Arable land code	Sector	Standard Conservation works	Tillage systems	Form of erosion active	Weighted contribution to soil erosion	Weighted contribution as a percentage
1	A1	Absent (95)	Conventional (80)	Sheet and rill (50)	95*80*50 =0.38	38
2	A2	Absent (95)	Conventional (80)	Sheet (20)	95*80*20 =0.15	15
3	A2	Present (5)	Conventional (80)	Sheet (20)	5*80*20=0.008	0.8
4	A2	Present (5)	Conventional (80)	Sheet (20)	5*80*20=0.008	0.8
5	A2	Absent (95)	Conventional (80)	Sheet and gully(70)	95*80*70 =0.53	53
6	A2	Absent (95)	Conventional (80)	Gully(50)	95*80*50 =0.38	38
7	A2	Absent (95)	Conventional (80)	Sheet and gully(70)	95*80*70 =0.53	53
8	A2	Present (5)	Conventional (80)	Sheet (20)	5*80*20 =0.008	0.8
9	LSCF	Absent (95)	Conventional (80)	Sheet (20)	95*80*20 =0.15	15

Figure 2: Grassed contour ridge in a protected field in a newly resettled A2 farm (Gambira farm)

Figure 3: Gully erosion working in an unprotected field in a newly resettled A2 farm in Mutoko District

Figure 4: Unprotected field showing activity of sheet erosion in a newly resettled A2 farm in Mutoko District

Figures 3 and 4 were taken from the same field in an A2 farm in Mutoko district. This field did not have conservation works, yet the field's gradient was not gentle. As a result, gully and sheet erosion occurred in the field. Table 4 shows detailed analysis of arable lands and the weighted percentage contributions to soil erosion. The highest contribution was 53 % and was obtained from arable land

codes 5 and 7. These fields showed signs of excessive sheet and gully erosion. The least contribution was 0.8% and this was on arable land codes 3, 4 and 8 (See table 6). These fields had conservation works existing and these were properly done. The contour ridges of the fields had properly matured with a turf of runner grass covering them. On tillage, all the fields investigated were tilled using the conventional method which contributes a lot to erosion as was stated earlier in the paper. There was no field where zero tillage was being practiced.

Dams

Fourteen earth dams were visited during the study. In terms of relative size, eight were found to be in the small category, four in the medium category and two in the large category (See figure 5). Five earthen dams of the fourteen assessed dams were breached. Of these five breached dams, four caused the development of gullies (Figure 6).In terms of siltation signs, eleven earthen dams had positive signs of sedimentation (See figure 10) whilst the remainder did not. Of the five breached dams, three were in the small category whilst two were in the medium category. None of the five large dams breached.

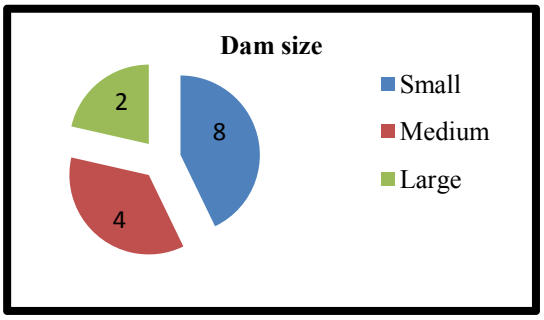

Figure 5: Size class distribution of dams.

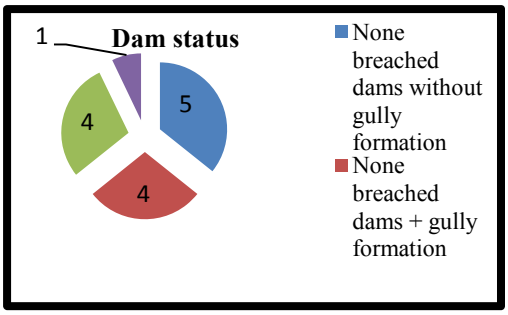

Figure 6: Dam status in study area

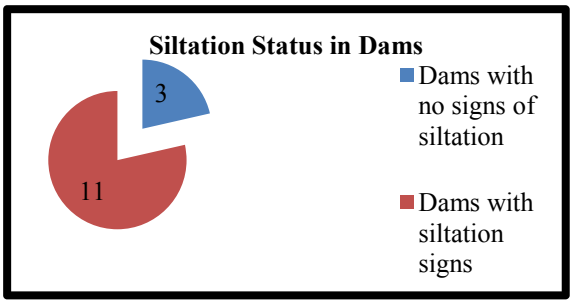

Figure 7: Number of dams with and without siltation signs in the two provinces.

Eight dams contributed to soil erosion whilst six did not. Of the eight dams, four had breached (See figure 8) and four had not breached (See figure 9) but had eroded the spillway channel (See figure 6). Only one dam breached without causing soil erosion. As for siltation, 11 dams had signs whilst 3 did not.

Figure 8: Section of collapse Munene dam wall in Mashonaland east province

Figure 9: Gully formation on faulty spillway of the Chidziva-Dahwe dam in Mashonaland Central province

Figure 10: Spillway section of the Chidziva-Dahwe dam in Mashonaland Central province heavily silted

Dam Code	**Status**	**Slope class**	**Soil erodibility rating**	**Water erosion rating and score (E) (%)**	**Dam size classification and weighting (S) (%)**	**Contribution to Degradation (%) $E*S/10^4$**
1	Breached +big gully+SS	Moderately steep	Low	Very high (60)	Small (10)	6
2	Breached + small gully+SS	Moderately inclined	Moderate	Moderate (10)	Medium (20)	2
3	Not breached +big gully at spillway section+NSS	Very steep	Low	Very high (60)	Large (70)	42
4	Not breached +no gully formations+NSS	Level-very gentle	High	Very low (1)	Small (10)	0.1
5	Not breached + no gully formation +SS	Gentle	High	Low (4)	Small (10)	0.4
6	Breached +big gully+SS	Very steep	Low	Very high (60)	Small (10)	6
7	Breached +small gully formation+SS	Gentle	Moderate	Moderate (10)	Small (10)	1
8	Not breached +big gully at spillway+SS	Very steep	Low	Very high (60)	Medium (20)	12
9	Not breached +no gully formation+SS	Gentle	High	Low (4)	Small (10)	0.4
10	Not breached +big	Very steep	Moderate	Very High (60)	Small (10)	6

	gully at spillway+SS					
11	Not breached +no gully formation +SS	Gentle	High	Low (4)	Large (70)	2.8
12	Not breached +big gully at spillway +NSS	Very steep	Low	Very high (60)	Medium (20)	12
13	Breached + no gully formation +SS	Gentle	Moderate	Moderate (10)	Small (10)	1
14	Not breached +no gully formation+SS	Gentle	High	Low (4)	Medium (20)	0.8

Results in table 7 showed that of the fourteen dams, five where properly constructed and the rest were not. The properly constructed dams had contributions to degradation due to erosion ranging from 0.1% to 2.8%. Dam code 3 had the highest contribution to degradation due to soil erosion of 42%. This dam was in the large category and was not breached but had a big gully at the spillway outlet. Dam code 4 had the least contribution to degradation due to soil erosion of 0.1%. This dam was in the small category and was not breached and did not have a gully at the spillway outlet.

Table 7: Dam status, soil erodibility rating, slope class, water erosion rating and scoring, dam size classification and weighting and percentage contribution to land degradation (Taken from tables 2, 3, 4 and 5)

NB. If a dam has breached, spillway channel slope will be replaced by the slope of the new channel or gully formed after breaching of dam.
SS: Means siltation signs; NSS: Means no siltation signs.
E: Water erosion score (%)
S: Dam size weighting (%)
Final weighted contribution to degradation due to erosion is found by the relationship: $E*S/10^4$

DISCUSSION

Judging from the results in tables 6 and 7, one is tempted to think that Zimbabwe does not have existing and abiding laws concerning the environment. However, UNEP (1997) cited in Chitiga and Chigora (2010) proves to the contrary. The environmental laws have been in existence in Zimbabwe since 2002.The implementer and enforcer of these environmental laws is the Environmental Management Agency (EMA). Some of the responsibilities shouldered by EMA are to provide for the sustainable management of natural resources and protection of the environment; the prevention of pollution and environmental degradation; the preparation of a National

Environmental Plan and other plans for the management and protection of the environment (EMA, 2011). However, signing agreements and enacting legislations is not enough when it comes to environmental management (Chitiga & Chigora, 2010). Implementation of these laws is equally important.

The question to be paused at this juncture is why soil erosion is increasing by the day when the nation of Zimbabwe has such a vibrant law in place? Tables 6 and 7 have shown that land management principles are not in use. As a result, sustainability of the precious resources (land and water) is being compromised. 67% of arable lands investigated were found either insufficiently protected or completely unprotected with contribution to degradation ranging between 15% and 53%.This shows an inverse correlation between catchment area management and soil erosion. This is so; because catchment area management incorporates sustainability and this is greatly compromised in either insufficiently protected or completely unprotected fields due to soil erosion.

The study also showed that because of lack of conservation works in the fields, gullies had developed (See Figure 3). Active gully erosion was shown to be occurring in arable land codes 5, 6 and 7. Land reclamation would be necessary if these lands are to be used again productively in the future. This proves yet another dimension that sustainable land use is always in concordance with proper catchment management. Unsustainable land use is synonymous with environmental degradation (a great stride towards desertification), which eventually leads to social and economic decay.

In some parts of Zimbabwe, it is estimated that 100 tons of topsoil per hectare is lost a year due to unsound land use practices (Manjengwa and Stiles, 2000). Maposa et al (2010) also pointed out that if care on land management is not undertaken with a sense of urgency, Zimbabwe will be the next Ethiopia. The massive land acquisition that occurred in Zimbabwe meant that there was a substantial movement of people from communal areas into the former white commercial farms (Maposa et al, 2010).This was done without proper land use planning, a very important component of catchment management. Therefore, proper land use planning was sacrificed from an environmental point of view (Maposa et al, 2010).

Earlier on, it was stated that the total number of allocated A1 and A2 farms for the two provinces was estimated at 1295 (Utete, 2003). The newly resettled farmers opened up new fields and this resulted in change in land use. Though the issue of land use change was not investigated in this paper, it is worth mentioning and was also mentioned in Maposa et al (2010) and Chitiga and Chigora (2010) with regards to the land reform program. Land use change affects especially the terrestrial carbon sequestration process. Arable lands are less effective carbon sinks as compared to

the woodlands destroyed in opening up fields. This results in more carbon dioxide existing in the atmosphere thus promoting climate change. Climate change results either in increased flooding or increased droughts. This affects catchment management. Flooding results in increased erosion and river siltation. Droughts increase water scarcity. Climate change impacts negatively on both natural and human systems.

Results on dams showed that eight dams caused land degradation due to soil erosion. Of these, one dam (Dam code 3) had the maximum contribution to degradation of 42% which is very high. This dam was in the large category showing that the bigger the dam the higher its contribution to land degradation provided it is not properly designed and constructed. This shows poor catchment management in the design and construction of earth dams. Results in table 7 showed that soil erosion was as a result of breaching or a poorly designed and constructed spillway (as is the case with Dam code 3) and its channel that conveys floodwaters back to the main river system (See figure 9). Breaching is as a result of construction flaws, seepage/ piping, overtopping and siltation (Mufute, 2007). It was shown that a breached dam (depending on size) can cause great damage to the environment and usually causes gully formation (See figure 11). Examples are dam codes 1and 6 that had a contribution to land degradation of 6% each. Figure 11 below shows extensive land degradation, an antithesis of sustainable land management. This was caused by Nyabopote dam of Mutoko district that had breached upstream of the gully. The dam (See figure 12) was once used for irrigating 50 Ha of arable land besides livestock watering.

The dam's embankment collapsed around 2002 due to scowling and excessive water inflows whose pressure probably was stronger than the wall could withstand. The embankment also had trees growing on it. This is also another good sign of poor catchment management manifesting as poor dam maintenance. The gully that resulted was estimated to be about +20m wide, 3m deep and more than 50m long. All the washed away soils certainly found their way downstream as sediments. This resulted in increased siltation of the river systems downstream of the now breached dam. Results have also shown that 11 of the 14 investigated dams had signs of siltation.The effect of sedimentation in a dam is that it reduces the dam's yield both in quantity and/or in reliability (Van Den Wall Bake, 1985).

Results have also shown that soil erosion on re-settled farms (see table 6 and figures 3 and 4) can lead to siltation. The edge of arable land with coded 7 is about 150m from the dam coded 14. The field did not have conservation works yet its slope was not gentle. Gullies formed in the field and

sheet erosion was active. Signs of movement of sediments from the field towards the dam were quite evident. This was justified by Chitiga and Chigora (2010) who said that activities of the resettled farmers are the major perpetrators of soil erosion, which constitutes poor land management. There was a possibility of lack of knowledge of sustainable agricultural practices among the resettled farmers. However, this study lacks on this evaluation to prove whether this assertion is true or false, though results seem to point that way. There is need for resettled farmers to be taught of the importance of conserving their environment so that the future generations would also benefit. This, however, has financial implications.

It's worth noting that the Zimbabwean economy has been on a downward spiral for about two decades. This down turn of the Zimbabwean economy had a crippling effect on activities of departments responsible for the environment. This is true judging from results obtained in tables 6 and 7. The laws are in place but implementation is lacking, hence the results obtained. The study earlier on stated that 67% of arable lands in the two study areas were found either insufficiently protected or completely unprotected with contribution to soil erosion greater than 25%.

Some of the eroded material eventually finds itself in river systems thus contributing to siltation. There is therefore, an inverse correlation between proper catchment area management and soil erosion. Siltation is regarded as one of the greatest risks to the failure of small dams especially in communal areas where environmental protection practices are absent or ineffective (RELMA, 2005). Results, however, did not show whether or not this statement is true. They only pointed to the existence of siltation problems in dams (see figure 7). The degree of siltation varies considerably depending on the condition of the catchment area (Maposa et al, 2010). The condition of a catchment area depends fully on its management. Thus, a poorly managed catchment also means a catchment in bad condition. A study in Cajamarca, a province in Peru showed that the encroachment by cattle owners on marginal land caused serious environmental degradation to the region's watershed due to deforestation. The result was increased soil erosion, reduced water quality and quantity and loss of biodiversity (UN-HABITAT, 2005).

Figure 11: Gully formed downstream of breached dam

Figure 12: Breached section of embankment of Nyabopote dam in Mutoko

Without appropriate design, construction and maintenance, small dams eventually fail, depriving the communities and animals of the much-needed water that is vital for sustenance of life (Mufute, 2007). About 95% of the earthen dams' embankments did not have proper maintenance. Trees, termite mounds and in some cases cattle paths existed on the embankments of these dams. This is a manifestation of poor catchment management. The results also show that the steeper the gradient of the spillway channel and the smaller the erodibility factor of the spillway channel the greater the contribution to soil erosion. This again shows that proper catchment management also deals with proper designing and construction of earthen dams.

Another very important question is: Who is supposed to be in charge of soil and water conservation issues in the catchments? Soil and water conservation is a broad subject that requires a coordinated and integrated approach. However, sometimes duplication of efforts is realized. Currently, there has been confusion between the AGRITEX personnel and Mechanization department personnel as to who is supposed to be in charge of soil and water conservation issues in the arable lands. For there to be an effective Soil and Water conservation, a collaborative approach is required by all relevant stakeholders and this must includes the land holders .In Colombia it was noted that their legislation

and competence for the use, management and protection of natural resources are scattered in different sectors which frequently result in conflicts between state officials, duplication of efforts, gaps in the development of activities and ultimately failure by the state to deliver services to its people (UN-HABITAT, 2005).

CONCLUSION

This paper has shown that though laws concerning environmental protection exist, they are not being used effectively. EMA was created for that purpose but it is not being effective as land continues to be eroded. The study has shown that poor catchment management at farm level actually results in loss of arable land through erosion. This is shown clearly from table 6 where all arable lands without standard contours in place had high weighted percentage contributions to soil erosion ranged from 15% to 53%. This means that the sustainability of high potential agricultural land is under serious threat as a result of soil erosion. Soil erosion results in the washing away of the precious top soil, responsible for plant growth and infiltration of rain or irrigation water. This reduces the usefulness of such affected arable lands as crops grown on it can't thrive due to lack of soil fertility. It was discussed earlier on in the paper that catchment area management incorporates sustainability and this is greatly compromised in either insufficiently protected or completely unprotected fields due to soil erosion. Soil erosion also tends to increase sediment yields in a catchment, thus threatening river systems and dams through either reduction of storage capacity or worse still through dam failure. River systems would also include aquatic life.

The paper proved that the river systems and dams are also silting, thus disturbing aquatic life and reducing yield in dams. This negatively affects environmental sustainability and creates economic and social problems. If erosion and river siltation are occurring at this pace, sooner or later most of our river systems will be silted. This tends to reduce available water as capacities of river channels and dams are reduced. This in turn will affect the livelihoods of societies that depended on the affected rivers and dams. Wild life and domesticated animals will not be spared either. Aquatic species will die and available water for use by the environment also drops.

The paper also noted that land redistribution results in land use change as woodlands are converted into fields through rampant felling of trees. This land use change normally affects especially the terrestrial carbon sequestration process. Arable lands are less effective carbon sinks as compared to woodlands destroyed in the process of opening up fields. This results in more carbon dioxide existing in the atmosphere thus promoting climate change. Climate change results either in

increased flooding or increased droughts. Either of the two impact negatively on both natural and human systems. It can safely be concluded that Land management and river system management (which would include dams) are directly related and cannot be carried out separately as it has been shown from the study that the former affects the latter.

RECOMMENDATIONS

This paper recommends a holistic approach to catchment management. This must link up social and economic development with the protection of natural ecosystems and appropriate management links between land and water use. It also calls for the integrated management of land, water and living resources, a strategy that promotes conservation and sustainable use in an equitable manner. The paper also calls for the empowerment of the EMA so that they will be in a position to do their environmental policing properly. EMA should also work hand in glove with other government departments like the Mechanisation department on soil and water conservation issues both in the old and newly resettled farms. All arable lands must be inspected by the department of mechanisation in conjunction with EMA and if the fields lack the conservation works, they must be pegged and the contour ridges must be constructed. That way, land can be used sustainably. Failure to stick to these requirements by a farmer must be penalised. A negative incentive of some sort must be agreed upon by EMA and the relevant stakeholders. There is also need for land holders to be taught about catchment management and its importance in preserving their lands and water bodies. Sustainable utilisation of these very important resources must be mastered by all.

All relevant stakeholders should understand the need for an integrated approach to catchment management. They should contribute towards the creation of a proper land use plan that embraces sustainability. There must also be need for integrating economic development and the management of the environment. To achieve this, all hindrances to the integration process must be removed and the process must receive the necessary financial support so that the integration process is fully realised. All dam designs and construction must be done according to laid down principles as spelt out by the Ministry of Water development manuals on design and construction of dams.

Last but not least, this study was a reconnaissance survey whose time allocation per province was limited to only five days. Financial resources were not permitting for justice to be done on this very important undertaking. The study was rather sketchy and the researchers' overall intention was for government to have a refocus on soil and water conservation issues at national level for the benefit

of future generations. It is, therefore, the sincere hope of the authors that a deeper study is done to further look at the issues highlighted by this paper.

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Climate change, institutional arrangements, sustainable agriculture and climate change adaptation in Chivi District, Zimbabwe

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ABSTRACT

The study conducted indicated people's perspective on climate change that shift in rain season, increase in temperature, decrease in precipitation and droughts in Chivi district as some of the evidence of climate change. Institutions that are involved in farming are faced with challenges in tacking land management and promoting sustainable farming methods. The decentralization of powers from chiefs to village heads resulted in people practicing steam bank cultivation and cropping on steep slopes. The exclusion of chiefs in land allocation is resulting in people being allocated land in wetlands owing to the destruction of these resources. Conservation farming and other water and soil and conservation techniques have been embraced by people but contributing little to agricultural production due to labour involved. Some of the farming practices that are being used by agricultural extension workers does not promote soil and water conservation but rather were designed to reduce water logging. The extension workers don't have enough resources and transport to effectively carry out their duties. People in the district can adapt to climate change through small scale irrigation schemes, increase in the uptake of soil and water conservation techniques.

Keywords: Climate change, Institutional arrangement, Sustainable agriculture and Climate Change Adaptation.

INTRODUCTION

Climate change has impacted negatively on the livelihoods of people in Chivi district and other parts of Zimbabwe and globally. Communities depend mainly on subsistence farming as their source of livelihoods. In trying to respond to the shocks of climate change, people have resorted to wetlands and stream banks cultivation as a means of enhancing food production. Some of these activities have negatively affected the environment through land degradation (Ziervogel et al., 2008).

Recent studies have shown that the climate is changing in Zimbabwe. Unganai (1996) observed for instance, that the annual rainfall in Zimbabwe had declined by 10% between 1900 and 1994. The El Nino Southern Oscillation (ENSO) phenomenon is a major influence on inter-annual variability of climate in Southern Africa. Major drought events have occurred many times in the 19th century (in 1916, 1922, 1926-27, 1946-47, 1967-68, 1972-73,1982-83, 1986-87, and 1991-92), with severe impacts. In these cases rainfall has dropped to as little as 30% of the annual mean (Orlove and Tosteson, 1999).

The rise in global temperature and recurrent droughts due to climate change have had negative impacts on the land resources as people unsustainably exploit the land to sustain livelihoods.People in Chivi district rely on subsistence farming as their main source of livelihoods. Due to recurrent droughts, people in the district are exploiting various land resources to supplement livelihoods, unsustainable farming practices such as cultivation in wetlands and stream bank cultivation to increase crop production. The institutions that are involved in agricultural production lack capacity to effectively craft ways to increase production. The study from which the paper is based was undertaken to assess the efficacy of governance mechanisms on sustainable agriculture in a changing climate and how such institutional frameworks have influenced climate change adaptation.

The study revealed that women's major duties are to till the land but there was a 20% disparity in the number of female and male's participation as more men participated in the study than women. Gender imbalance is the main reflection of the patriarchal nature and household's governance system at community level. However, according to FAO (1995), in the Sub Saharan Africa region, agriculture accounts for approximately 21% of the continent's GDP and women contribute 60-80% of the labour used to produce food both for household consumption and for sale. This denotes the weakness of the household as a unit on agriculture production as the man would be the sole decision maker in the household land management activities hence contributing little on land management. The study revealed that men spend most of their time drinking opaque beer and are responsible for managing finances which the women would have worked for which mainly would have come from agricultural activities. Social roles and responsibilities of women and men create different degrees of dependency on the natural environment. Women are usually the ones engaged in household subsistence activities that include farming and are more likely to cause degradation of forests, watersheds and agricultural land (Chagutah 2010).

The researcher used both quantitative and qualitative methods of researching techniques, including household interviews, focus group discussions, key informants interviews and focus observations. Secondary data sources were also used in this study. Data was analysed using Special Package for Social Sciences (SPSS).

METHODOLOGY

This study was conducted in Chivi district in Wards Number 3, 8, 16, 25, 28 and 29. The district is located in the dry region of Zimbabwe and covers an area of 3534 km². Long term climatic data (1913-2001) shows that the district receives an average annual rainfall of 545 mm (Kewero et al., 2003). The district is characterised by recurrent droughts (Dhliwayo, 2007), which seem to intensify with climate change.

A total of 140 households were sampled and interviewed representing 10% of the households in the six wards. These wards were sampled through stratified random sampling where wards sampled were categorised according to the distance from the Rural District Council (RDC). Purposive sampling was used to identify key informants. Questionnaires were used to solicit information on land management techniques, current climate change adapting strategies and land management practices. Heads of households were interviewed during the household survey

Interviews were also done with key informants, including one respondent from the Rural District Council (RDC), The Forestry Commission, Ministry of Environment and Natural Resources Management, Ministry of Agriculture, Mechanization and Irrigation Development and three Chiefs. Interviews were focused on assessing the efficacy on governance mechanisms of these institutions on sustainable agriculture and climate change adaptation. The key informants and household interviews were also complemented by three focus group discussions (FDG) that were conducted in Ward 3, 16 and ward 29, each group constituting of about 25 participants. The focus group discussions focused on sustainable agricultural techniques, current climate change adapting strategies, institutional arrangement and land management practices. Heads of Households were interviewed during the household survey. Some of the information from the above methodologies was verified through field observations that were used to corroborate information gathered from the household, FDG and key informants. Analysis of data was undertaken using the SPSS.

Climate change

Figure 1 presents the local perceptions of climate. A large percentage associated it to droughts, increase in temperature and shift in rainfall seasons. About 32.2% of the respondents indicated the main evidence of climate change is due to the shift in rain seasons and 7.1% highlighted that climate change is evidenced by the increase in temperatures and prolonged winter season which has prolonged to August. Rainfall season has shifted from October to November and December. About 60.7% of the respondents said that the evidence of climate change is drought and decrease in annual precipitation. The communities unanimously pointed out that the delayed onset has shortened the rainfall season as there is no extension of the same season. Shongwe (2011) observed also that the stimulated annual cycles in a warmer climate show a one month delay of the rainfall on-set and no shift in rainfall cessation months, thus implying shorter rainy season. According to Scoones (1996), within years, rainfall is also highly variable and the coefficient of variability for rainfall in Chivi District of Masvingo province during the month of January is 78%, with about 45% of years experiencing rainfall at least 25% longer than the long term average.

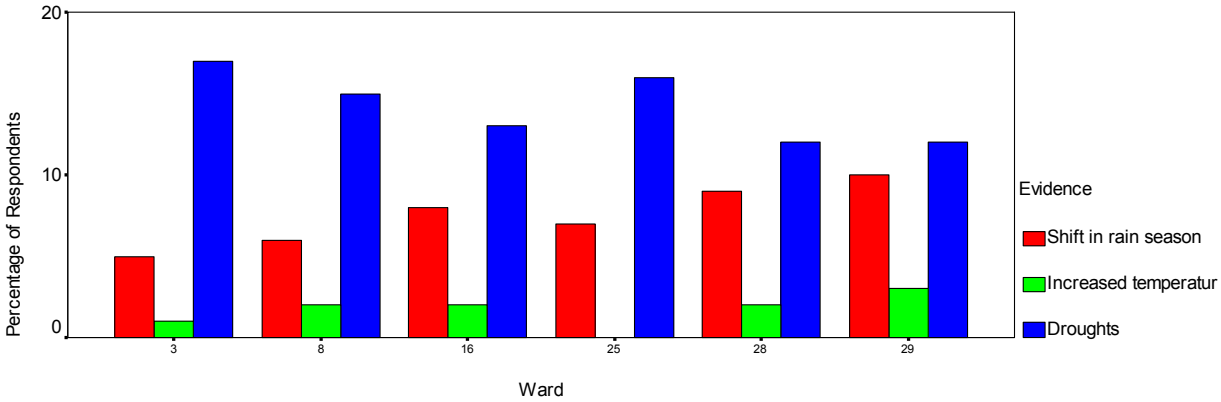

Figure 1: Evidence of climate change

Agricultural Activities

Figure 2 presents the different agricultural land- use types in Chivi district. It shows that 73% of the respondents use their land for crop farming, 26 % for grazing and 1% are into fish farming. It is clear from Figure 2 that agricultural activities (crop farming and livestock production) occupy a large part of land use in the study area. This was also confirmed during focus group discussions where participants highlighted that the major source of livelihood derived from land activities are farming and grazing, while other activities come as complements and / or alternatives. Murphree and Cumming (1991) agree that subsistence agriculture on communal land has characterized land use. Chenje et al. (1998) pointed out that in Zimbabwe, land is becoming a scarce resource due to immense agricultural and demographic pressure. Focus group discussions rated grazing -livestock

production as the second sources of livelihoods, but grazing land as a major challenge. Interviews made with Chiefs revealed that, grazing areas are un-controlled and cattle move freely from different villages, one ward to the other. The Chiefs interviewed indicated that they are no longer controlling stocking per household even though they are mandated to do so by the law because of droughts as a means to promote adaptation to climate change through livelihoods enhancement. Despite the presence of dams in the district, fish farming has not been developed to benefit the rural populace as food and income sources to complement crop production. These dams are also not being fully utilised for irrigation purposes.

In the district there are perennial rivers but the water is not being harnessed for irrigation, fishing and watering of livestock as a way to adapt to climate change and curb droughts.

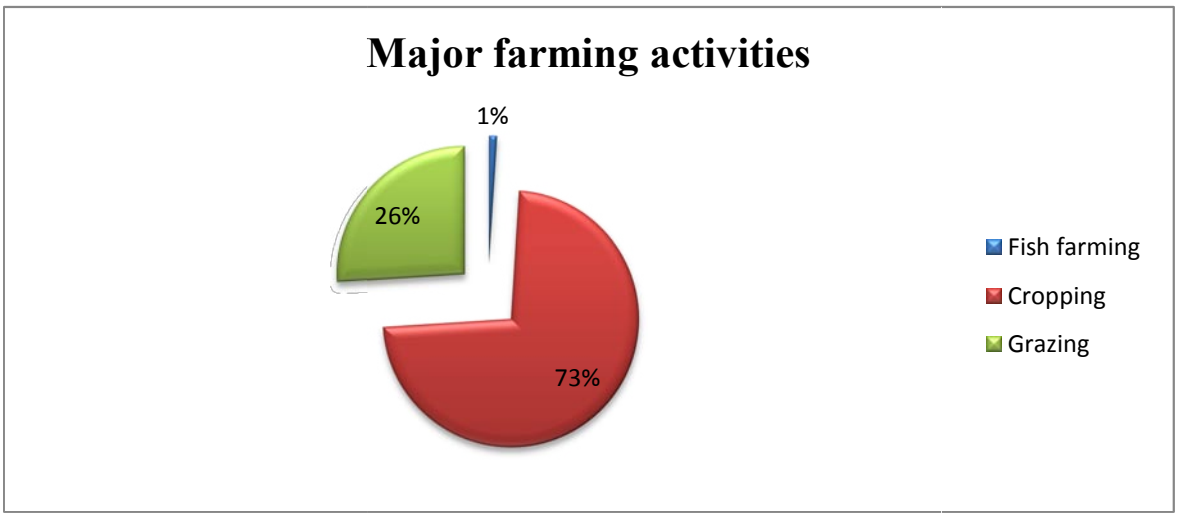

Figure 3: Agricultural activities in the district

Exploitation of land for agricultural production

Although people in the district are doing grazing, the practice is uncontrolled. As a result cattle move freely from ward to ward without any restriction creating paths and loosening soils, thus exposing soils to wind and water erosion. Chiefs are no longer controlling numbers of livestock per household even though they are mandated to do so by the law as this allows communities to adapt to droughts. People in the district use poles and thorny shrubs to fence their plots to protect crops from livestock. The Traditional Leaders Act (Chapter 29: 17) that is administered by chiefs is silent on fencing of fields using poles and thorny shrubs. The fencing of fields with thorny shrubs indicates a lack of a coherent policy that may control grazing instead of spending many poles and

thorny shrubs and trees as fencing materials to protect crops from livestock. Cutting thorny shrubs and trees for fencing contribute to the degradation of natural vegetation.

In ward 29 where there has been implementation of the Fast Track Land Reform Programme in the year 2000, vast tracks of land have been cleared as people opened land for farming and trees being cut for domestic construction purposes. Lue-Mbizvo and Mohamed (1993) indicated that in all the farming sectors, clearing of woodland for agricultural production is unregulated and encourages the conversion of forest land to crop land.

Little has been done by the Forestry Commission and the Environmental Management Agency to protect the destruction of the forest by communal people for the fencing of field and kraals. The Forestry Act (Chapter 19:05) states that it is the duty of the Forestry Commission to protect forests and woodlands including trees in cultivated land that are being exposed to deforestation by communal farmers as this practise may defeat agro-forestry. The organisation has mobility challenges at the district level because of shortage of human capital for monitoring of forests and woodlands as a result the district is managed by one person.

Due to the change in the local currency in 2009 from the use of the Zimbabwean Dollar to the United States Dollar, the Forestry Act continued to interpret fines in Zimbabwean Dollars instead of the United States Dollars as the responsible authority did not amend the Act to suit the current and present prevailing economic environment. EMA indicated that the Forestry Commission is finding it difficult to enforce the Forestry Act to protect trees from deforestation. This is leaving the Forestry Commission with limited legal enforcement rights to prosecute people who are found cutting down trees.As a result, the Forestry Commission is working with the police which have the power to enforce spot fine of $20 on a person found cutting down trees. EMA asserts that these spot fines are low hence continued deforestation by the communities. Interviews carried out with EMA, indicated further that when a person has caused damages to the environment; the person is exonerated by courts when there is no evidence of damage caused to property. This entails that courts have limited understanding on environmental and land management issues as this denotes the weakness of the current judiciary system on land management hence continued degradation of the land by communal people. Further more, EMA lacks human resources capacity to effectively monitor land management practices.

On the other hand, the RDC lacks human resources as it has only one officer who is responsible for coordinating land management issues at district level. The RDC has got community volunteers who enforce council by-laws and who were elected by the communities. The environmental monitor indicated that they took a month before paying fines to the council and those who fails to comply with the law are dragged to courts. However, during the focus group discussions, participants indicated that no one has been hauled to courts for land degradation, this indicates that these policies are non binding, and without any litigation measures from courts, people will continue destroying the land. Gumbo (2006) and Chimhowu (2009) indicated that the RDC is an institution with a long history of limited capital support, limited capacity, and poor financial base liable to make decisions on the bases of political rather than pragmatism.

Fines that are being charged by traditional leaders to protect the destruction of land for fencing poles to fence fields are too low (US$30 / goat) for cutting down a tree as this does not match with the damage caused to the environment. Interviews done with Chief Gororo, indicated that the laws which they use to prohibit deforestation, states that a person caught cutting down a tree is eligible to a fine of a goat but does not specify the size of a goat. He further pointed out that the fine is insignificant as offenders usually pay young goats as fine. Under the current gazetted regulations to prohibit deforestation, people will continue cutting down tress as a business to enhance their livelihoods as the fines are too low to curb deforestation. On the other hand, Chief Madyangove indicated that they don't enforce land management laws effectively due to fear of imprisonment and people who are found guilt seek protection from the DA's office. The fear by Chiefs to enforce the Traditional Leaders Act of 1998 confidently resembles conflict on land management within the same institution as the DA's office is responsible for supervising chiefs. There are no defined parameters of duties and extend to which the traditional leaders should exercise and execute their powers on land management issues.

Challenges faced in land exploitation

Figure 4 represents various challenges that communities in Chivi face in their efforts to harness local resources and obtain a livelihood. The study shows that 57.1% of the respondents consider droughts as the major challenge to exploit the land, followed by lack of adequate draught power (28.6%), lack of inputs for farming (7.1%). The remaining 7.1% considered poor soil fertility as an important challenge. Data obtained from the focus group discussions indicated that, majority of the participants had access to the government seed inputs scheme, but mostly in form of maize as this defeats the promotion of soil conservation techniques such as crop rotation. The continual issuance

of maize seed by government indicates a policy gap in promoting sustainable agriculture on crop diversification. The community also indicated that recurrent droughts have eroded their livelihoods base and major assets that include cattle. Village head Mutote of ward 25 indicated that the 2008 drought killed his 8 cattle and is now left with only two. He was used to manure for improving soil fertility in the fields but he no longer applies any organic manure. In ward 3, the agricultural extension workers are promoting manuring and compositing to increase soil fertility, but the methodology is being defeated as people don't have enough livestock to produce manure due to droughts. The lack of vegetation in the area is hampering the use of manure from compositing as tool for organic farming. Chenje et al. (1998) indicated that during the 1991-1992 droughts, more than 1 million cattle died in Zimbabwe.

Compositing that is being promoted by the extension workers is labour intensive as the community will have to walk for long distances to collect decayed leaves. During the interviews, respondents also pointed out that they don't have knowledge on how the compost can be made. Observations have shown that the biomass is very scarce in the district due to sparse vegetation. There is also a concern among community members that the extension workers promote more of these programmes to enhance food security and neglect livestock production as another source to enhance livelihoods and a way to adapt to climate change. Livestock production such as goats is more resistant to droughts and can provide an alternative source of food and income in the event of droughts.

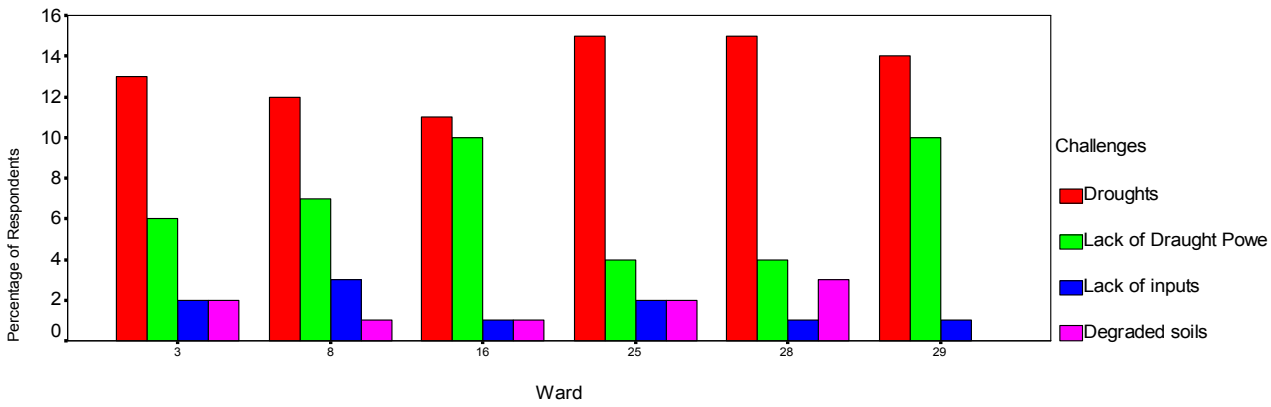

Figure 4: Challenges faced by the communities to exploit the land

Land degradation and poor farming practices

Figure 5 presents additional on-farm activities that are claimed by the community to cause land degradation. About 47.1% of the respondents perceived cultivation on steep slopes as the cause of

land degradation, 42.2% pointed out stream bank cultivation while 10.7% did not have knowledge to the causes land degradation. These variations in the percentages of responses indicate the variable understanding of environmental issues that is often found in many communities. It is interesting however, that farmers recognise and are aware that some farming practices have negative impacts on the environment. With sufficient extension services, more environmental education supported by effective institutional frameworks may be transformed into more sustainable practices.

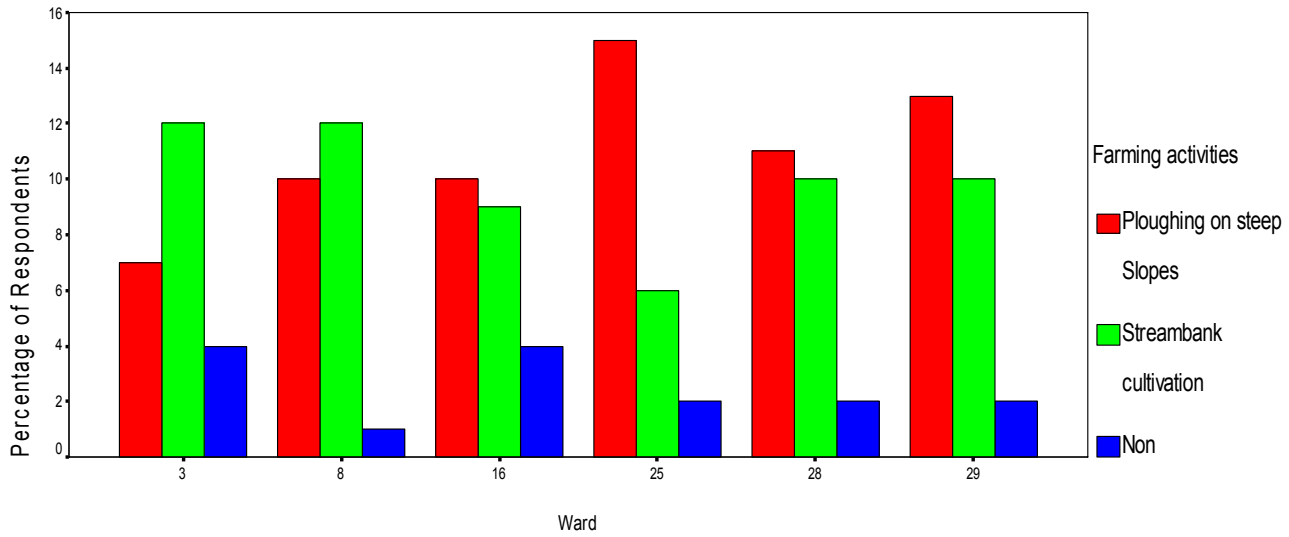

Figure 5. Farming activities that cause land degradation in Chivi District

In Wards 25, 28 and 29 where more people are cultivating on steep slopes, the land is mountainous and as a result people are forced to cultivate in steep slopes despite of the existence of land management laws that prohibit mountainous degradation. This demonstrates inadequate enforcement of the existing legislations. As indicated during field survey, there were claims by respondents that since the traditional leaders, the Chiefs, are not currently responsible for the allocation of land, the village heads who have been bestowed with that responsibility are not diligent enough. Chiefs only receive reports from the village heads on people being allocated stands. Village heads receive bribes from people so that they can be settled in ecologically sensitive areas, mainly due to due to shortage of land for farming in other parts of the landscape. This further demonstrates existing weakness in the institutional framework related to land management of the area.

The research also found out that communal farmers are also practising by stream bank cultivation. The recent empowerment of village heads to allocate land in the communal areas by the District Administrators seem to have resulted in people being settled in the river valleys and wetlands

without much regard to the environmental consequences. Chief Gororo pointed, for instance, that exploitation of those areas has caused considerable destruction of wetlands in Ward 28. Ostrom (1999) and Sithole (1997) argued that in Zimbabwe, the failure to achieve sustainable resources utilization has been attribute to the continued focus on management without considering of the institutional frameworks within which that management is effected. Gumbo (2006) indicated that the cultivation of wetlands and stream banks in Zimbabwe driven by the search for fertile soils and moistures by local farmers may be difficult to change in the face of severe food shortages due to droughts. Similar experiences were reported by Majule and Mwalyosi (2005) who studied wetland cultivation in southern Tanzania. They found that while such practice contributed significantly to food security of the area especially by supporting dry season cultivation, there were several environmental challenges, including siltation of water courses, pollution and increased water resource-related conflicts.

Land management monitors appointed by the RDC to monitor stream bank cultivation and other land management practices, indicated that they have limited capacity as they work within the confines of the traditional leaders. Monitors fear victimization from the local communities and this hinders the effective enforcement of by-laws. On the other hand EMA indicated that it lacks the human and transport resources to effectively monitor environmental management practices in the entire district. The institution reported to have no transport facilities specifically allocated for the district. In addition, the district does not have enough staff. The latter farther complicates environmental management in the area and constrains staff mobility.

Soil and Water conservation Techniques

About 59% of the people interviewed during this study indicated that they don't practice soil and conservation techniques. Majority of farmers (86%) who reported to practices soil and water conservation reported to practice conservation farming (traditionally known as Dhiga udye) (Figure 6), while others indicated that they used contour ridging and infiltration pits. A few farmers reported to practice crop rotation.

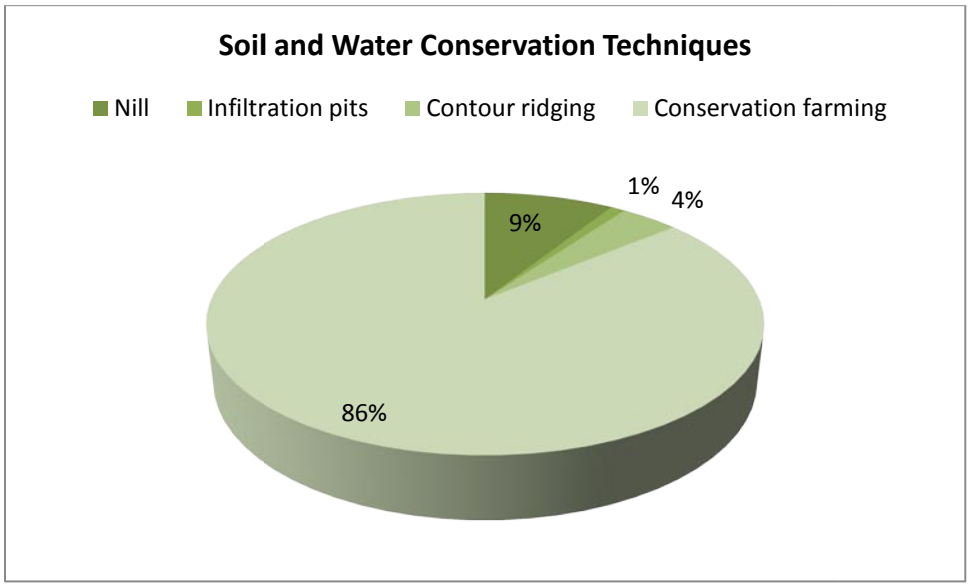

Figure 6. Soil and Water conservation Techniques practiced in Chivi district

Most participants expressed ignorance on the value of using soil and water conservation techniques. This indicates an inadequacy of extension services that could deliver to the farmers' knowledge on the soil and water conservation as well as the techniques that could be used. There was also a concern among the respondents that they do not have the appropriate tools and labour to construct conservation structures like contour and infiltration pits. Observations made in Ward 16, showed that most of contours were designed to drain water away from the fields as opposed to holding water within the fields, the aim being to reduce water logging. This practice/model does not fit into the present climatic condition that is mainly characterized by droughts that requires retaining as much water in the field as possible. Thus there is need to promote soil and water conservation practices that adapt to the prevailing climatic conditions ,possibly through increased training on climate change impacts and best practices that can address water plant shortage in a changing climate. Communities in Ward 16 and 25 claimed that extension workers do not visit their areas, while AGRITEX pointed out that those workers lacked adequate transport and this constrains their mobility.

Conservation Farming

Average production per household using non organic farming methods

The graph in figure 7 shows the average crop production for the households that are not using conservation farming. The highest average annual production is between 0.2 tonnes to 0.4 tonnes per household. The low production is attributed to low soil fertility, poor farming practices such as

monoculture where farmers plough same crop on the same piece of land. People in the district are poor hence they cannot afford to buy other crops such as sugar beans and other crops for intercropping. The size of land that is being put under cropping has been reduced by 50% due to shortage of seed and draught power hence little change in agricultural production. Drought is also contributing to poor production by farmers. Due to droughts, soils in the district can not hold water for a long time as they are sandy hence high evaporation. Crop production average of 0.6 tonnes to more than one tonne is notable in wards 8, 16 and 29, this is possibly because of wetlands in the wards and some small scale dams hence increased production. Ward 29 is a resettlement area, as a result, the soil are still virgin hence increased water retention capacity.

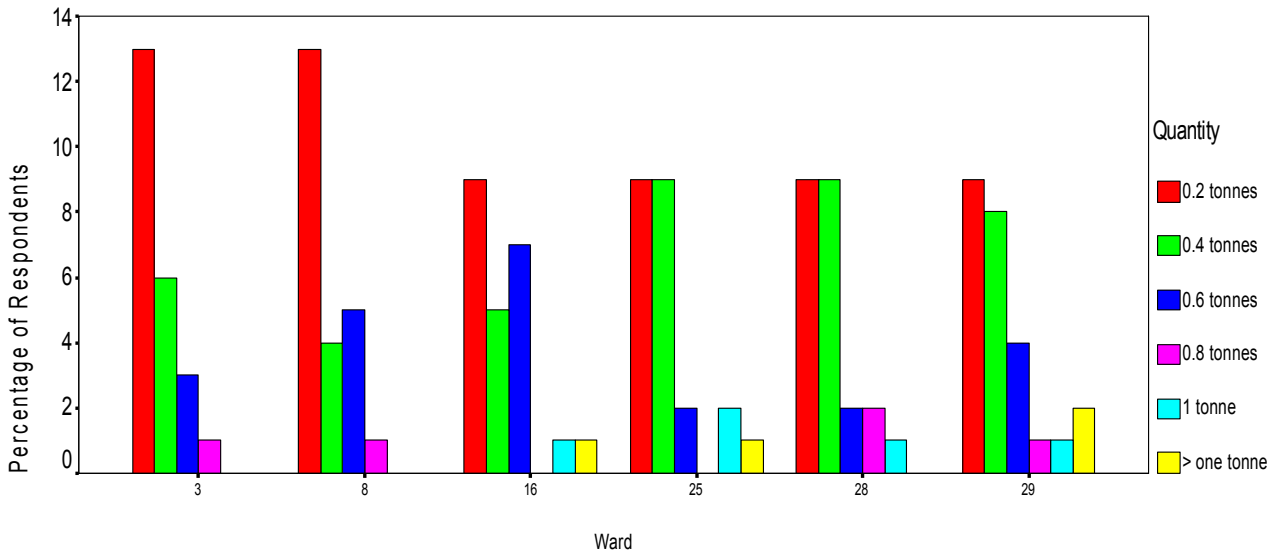

Figure 7: ***Average production per household using non organic farming methods***

Average production per household using organic farming methods

The graph (Figure 8) shows that there is an increase in crop production for households practicing organic farming. The increase is marked between 0.4 tonnes to 0.5 tonnes compared to 0.2 tonnes for households not practicing conservation farming. Although there is a significant increase in crop production, conservation farming is labour intensive and it was noted that the land put under crop production under this scheme is very little, hence this can only benefit when used for subsistence not commercial. This coincides with findings obtained in Chivi ward 21 by Gukurume et, al. (2010), that conflicting perceptions can be seen in that conservation farming has been aptly called "Diga udye" (euphemism for dig and survive) by its exponents, while for the majority of local farmers in ward 21, labeled it is "Diga ufe" (euphemistically meaning dig and die). They were saying this in light of the incongruence of the investment put in this conservation farming vis a' vis

the benefits and outcomes of this practice. To the villagers, the costs of engaging in conservation farming far outways the perceived benefits of this aforesaid farming technique.

The concept is also jeopardized by the fact that, the organic farming technique promotes the digging of basins using hands yet the people in the district use donkeys for farming, so they see no value in digging using hoes whilst the donkeys can be used for such activities. Gukurume et, al. (2010) concur that people in the district see no value in digging basins, while they have donkeys for draught power as being revealed by one respondent saying that it will be of no use to dig basins whilst they have donkeys that can be used as draught power. Dhliwayo (2010) noted that conservation farming has been difficult for many people to accept because it goes against many of the people's traditionally cherished beliefs. He argues that many people have questioned the feasibility of merely growing without ploughing the land first, which is the traditional blueprint. Even where appropriate land management interventions have been fused into the traditional farming practices, conflicts, contradictions, and power struggles between 'experts' (that is, agriculture extension workers, relief workers, and other government officials spearheading the implementation of the project) have often militated against the achievement of the much heralded food security in these drought-prone areas.

The fact that conservation farming is promoted by Non Governmental Organisation (NGOs) that include Care International with other local Non Governmental Organisations where participants benefit free seed and fertilizer cause it difficult to measure its success. Most farmers participate in order to gain free inputs. There is no buy-in and full participation between the local people and the NGOs that promote this programme. In areas that are not targeted by NGOs, like ward 29 which is a resettlement area, the uptake of the promoted conservation farming is very low. When the interventions (conservation farming) by these NGOs came to an end, 50% of the respondents in the focus group discussions highlighted that they will resort to their conventional farming methods as they will no longer be benefitting from free seed maize.

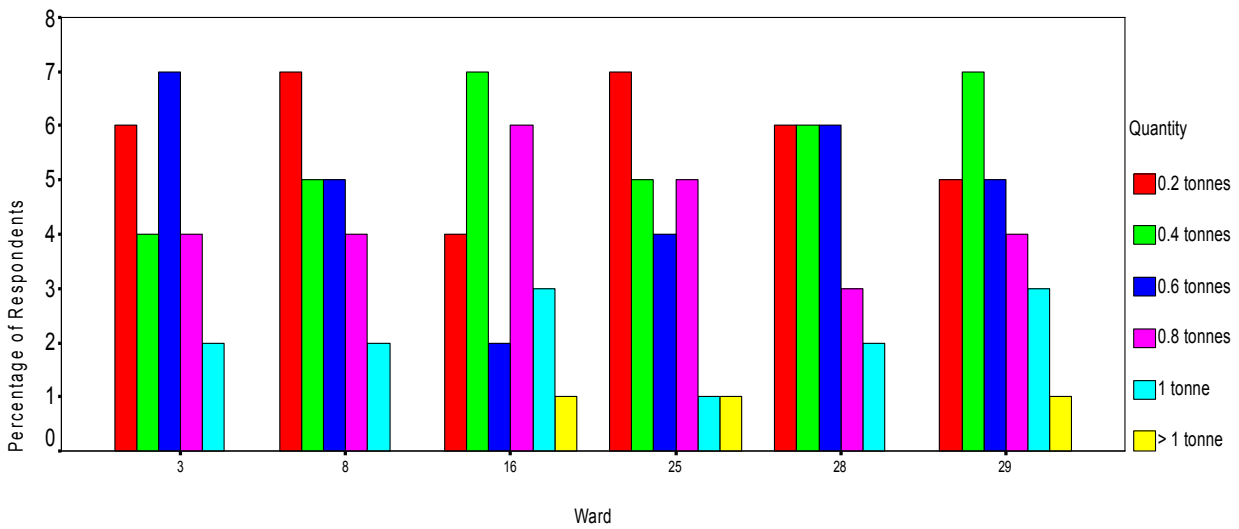

Figure 8: ***Average production per household using organic farming methods***

Climate change perception, impacts and adaptation

Regarding current and potential adaptation options, about 50.7% indicated small scale irrigation projects (Figure 9) to be the major solution to reduce dependency on rain-fed agriculture. Other respondents (39.3%) considered co-operative garden projects to be an important means for adapting to impacts of climate change. Rural electrification was mentioned by a few respondents (7.1%) to be an important approach to facilitate community adaptation to climate change impact. Some farmers (2.9%) considered agroforestry as a sustainable way of adapting to climate change and averting hunger. The various products from agroforestry trees may contribute to alleviating poverty while the trees are important in carbon sequestration. However, it was surprising to note that there was no mention of organic farming and the communities should be sensitised and enough education should be issued on the importance of organic farming in the changing climate.

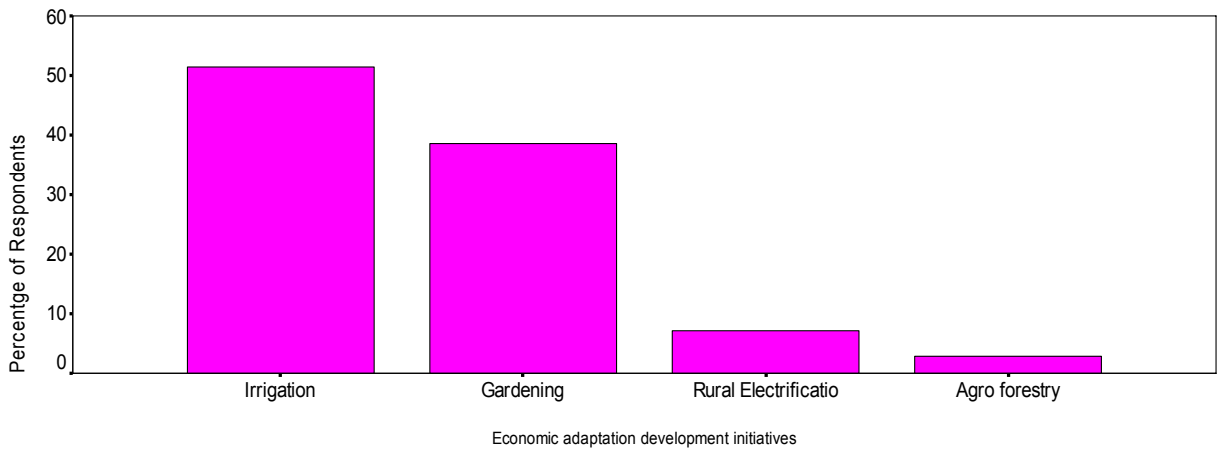

Figure 9. Current and perceived climate change adaptation strategies in Chivi District

The mentioning of rural electrification by the communal people highlighted that the need for rural electrification is very essential as this will enable them to practice small scale irrigation through drilling of electrified boreholes and also diversification into other forms of agriculture besides crop farming such as poultry production.

Conclusion

Climate change can resonantly be dealt with through a sound institutional framework that is aimed at increasing the adaptation by communities to climate change. The change in climate and increased droughts has affected food security. Sustainable agricultural techniques should be promoted and local institutions should be capacitated to respond effectively to the effects of climate change. The linkages between sustainable agriculture, institutional frameworks have been established including the ways in which communities are responding to climate change impacts. Generally, the present institutional frameworks have appeared to be inadequate to promote sustainable agriculture and promote adaptation to impacts of the changing climate.

The people in Chivi district are using organic farming methods to increase production but the programme has not been supported enough by government and hence there is not much benefit in the programme. The major ways of adapting to climate change in the district is organic farming leaving out other forms of adaptation such as irrigation, promotion of livestock production and aquaculture. The farming in these communal areas is not supported by credit schemes in order to finance farming activities.

The recommendations from the findings may include building capacity of stakeholders that are involved in sustainable agriculture including extension workers. The training that is being offered to extension workers should have a bias towards climate change so that they can be able to effectively deal with climate change. Enough resources should be availed to the said group so that they can be mobile and be able to execute their duties effectively. The government should promote soil and water techniques in regions that are drought prone such as Chivi district supporting the schemes with adequate machinery to promote its uptake in these communities.

The Chivi District Council and Traditional leaders must craft laws that control grazing and stocking in the district. There should be a harmonised approach in the conservation of local resources such wetlands that involve inclusion of all stakeholders whether the traditional, NGOs and the government. The government should initiate alternative approaches to adapt to climate change by the local people such as building of dams to increase aquaculture and irrigation production as a way

to complement organic farming techniques. Rural agriculture should be supported by credits schemes in order to increase production as the farmers will be able to access inputs that include seed.

Acknowledgement

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A remotely sensed surface water-rainfall model to understand the distribution of surface water in Southern African semi arid rangelands.

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ABSTRACT

In semi-arid rangelands water is a major constraint to livestock production and wildlife conservation. In this study, we tested the performance of the Modified Normalised Difference Water Index (MNDWI) to map both natural and artificial surface water sources in a semi arid region in the South-East Lowveld of Zimbabwe. Field data together with high spatial resolution images were used to determine MNDWI accuracy in mapping surface water. We also used annual rainfall and the number of remotely sensed water holes from 1999 to 2010 to develop a remote sensing-rainfall regression model for estimating the number of surface water holes. Next, GIS was then used to determine spatial and temporal dynamics in surface water by season in different land uses. Results show that MNDWI can successfully (Kappa= 94%) be used to map surface water in semi arid environments. Surface water was also significantly predicted from annual rainfall (r^2=0.98, p<0.01 for the wet season and r^2 =0.96, P < 0.01 for the dry season. A water gradient was also observed from the protected area towards the agricultural areas. Our results imply that surface water availability in semi arid environments is significantly affected by rainfall patterns.

Key words:Modified Normalised Differece Water Index, surface water, remote sensing, geographic information system, Southern Africa.

INTRODUCTION

Semi-arid ecosystems are water limited ecosystems (Hitchcock, 1996, Redfern et al 2005). These ecosystems have rainfall that ranges between 240mm to 600mm per year (Valeix et al., 2008) with high interannual variability with coefficients of variation being in the range of 25.6% (Chammaille-James et al 2007). Thus, the development of models to predict both natural and artificial surface

water distribution in semi arid environments is an important step towards understanding semi-arid ecosystems especially herbivore species distribution. This is because herbivores tend to adapt their home ranges according to water distribution constraints (Webb, 2008). For instance, a study in the Amboseli National Park in Kenya, found that during the dry season when water is scarce, 99% of herbivore biomass occur within 15km of surface water (Western, 1975). Thus, models to predict both natural and artificial surface water distribution are critical for rangeland management in semi arid ecosystems.

Although rainfall has been proven to strongly influence surface water availability across arid and semi arid environments at different time scales (Redfern,2005; Hibert et al., 2010;) there is scarcity of models to predict spatial and temporal distribution patterns in surface water availability as a function of rainfall. Several reasons could explain this scenario but the most prominent appears to be the limited availability of spatial data on surface water sources that can be readily combined with rainfall data to enable the development of surface water -rainfall models.

Apparently, most surface water data are often based on intensive fieldwork that provides only a snapshot of surface water distribution. For example, (Ryan, 2005) characterized surface water resources in the Kruger National Park based on field data. Chammaille-James et al (2006) also used field data to analyse surface water distribution in Hwange National Park. In this regard, new methods to frequently and accurately map surface water are critical if surface water-rainfall models have to be developed.

The development of remote sensing has added significant possibilities towards the understanding of spatial and temporal surface water distribution (Jones et al., 2006; Pérez et al., 2011). To this end, various remotely sensed indices have been tested in different ecosystems for the purpose of mapping the distribution of surface water from remote sensing imagery. Among these indices are the Modified Normalised Difference Water Index(MNDWI), the Normalized Difference Vegetation Index(NDVI) (Townshend and Justice, 1986; Tucker, 1979), the Normalized

Difference Water Index ($NDWI^1$) (Gao, 1996; Hardisky et al., 1983), the Normalized Difference Water Index($NDWI^2$) (McFeeters, 1996) and the Normalized Difference Pond Index (NDPI) (Clandillon et al., 1995; Lacaux, 2007) .In other studies, high to very high optical data sets were used to map small wetlands in the dry savanna areas of East Africa(Mwitaa, 2013).These indices have been applied with varying success rates in different environments. Among the above

mentioned indices, the MNDWI has been touted as the most superior in detecting and mapping surface water in temperate regions of the world (Xu,2006). However, whether MNDWI can successfully be used to map surface water in semi arid regions of Southern Africa has not yet been tested.

In this study, we tested whether and to what extent rainfall relates with the number of water holes in semi-arid ecosystems using 11 year surface water and rainfall data. We specifically tested whether we can predict the spatial and temporal distribution in surface water from Gonarezhou National Park (GNP), and its surroundings from rainfall data. We used a remotely sensed vegetation index (MNDWI) to classify water sources and determine the distribution of surface water sources. Next, we used regression analysis to test whether and the extent to which MNDWI derived from Landsat TM can be used to map surface water distribution. We then tested whether the number of surface water holes significantly differed along a gradient from protected areas (GNP) and the neighbouring agricultural areas.

METHODOLOGY

Study Area

The study was conducted in the semi arid region of the South East Lowveld of Zimbabwe (SELZ) (21° 40' S and 31^o40'E) which comprises a mosaic of land uses including Gonarezhou National Park (GNP), communal areas, small scale commercial farms, large scale commercial farms, private conservation areas and safari areas (Fig.1). The total study area is 9663.26 km^2, with 5053.15 km^2 (52%) composed of protected area and 4610.10 km^2 (48%) of adjacent agricultural lands in Chiredzi district of Zimbabwe.

In this region, water available to people, livestock and wildlife depends on rainfall which varies greatly among and within years with most of the annual precipitation falling within the months of November to April (Mares et al., 1985).

As a result, water availability may be limited for portions of the year or for several consecutive years because of frequent and widespread droughts (Webb,

2008). The study area receives rainfall totals ranging from a minimum of 84 mm to a maximum of 1118 mm per year (Torrence, 1981).

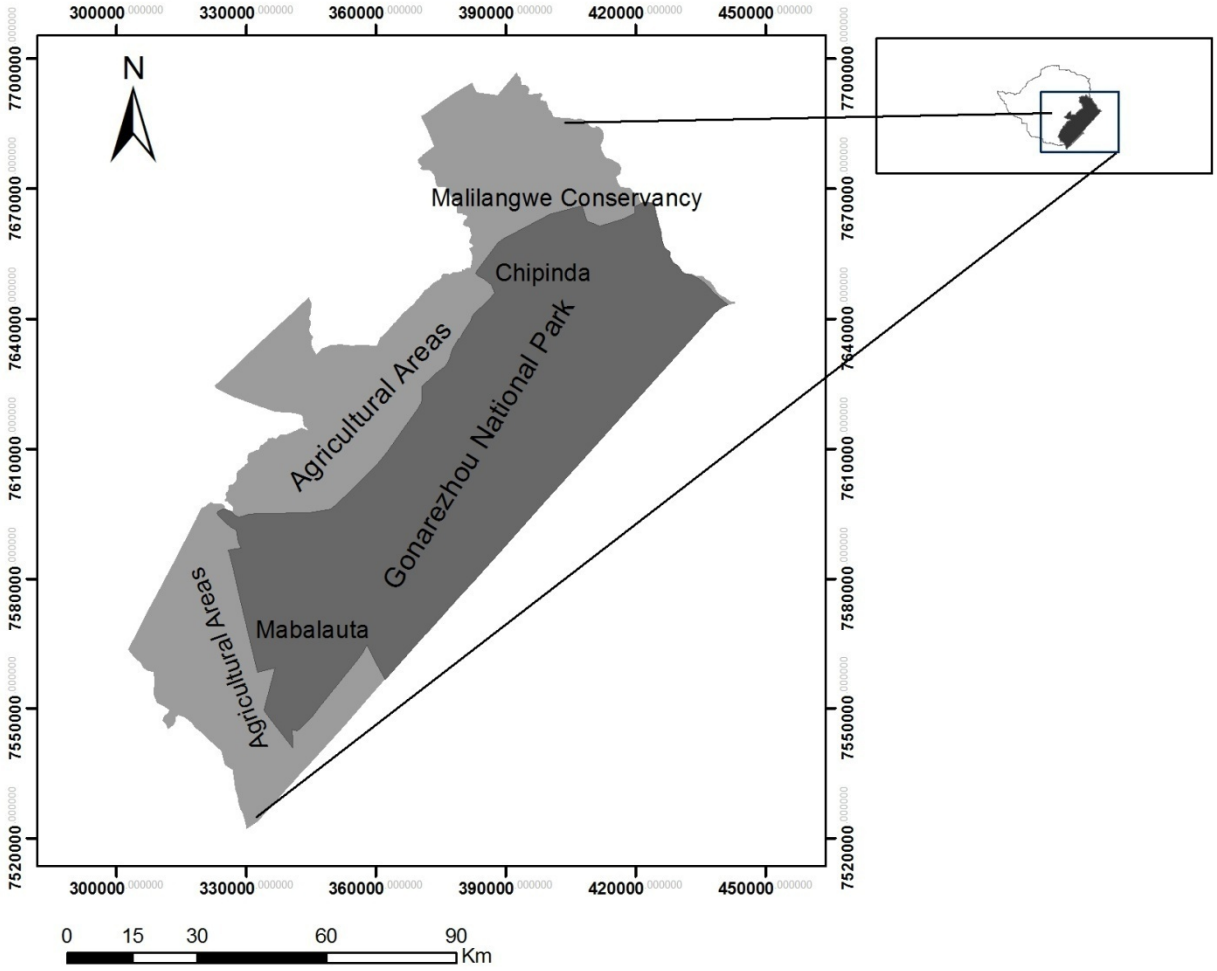

Figure 1.Location of the study area.

The SELZ is characterized by relatively low altitude of below 400m above mean sea level. Average daily maximum temperatures range from 27°C in June to 36 °C in January and minimum temperatures range from 8°Cin June to 24°C in January (Torrence, 1981).

2.2 Remotely sensed surface water data

In order to generate a complete view of water distribution during the wet and dry seasons, Landsat TM images that gave cloud free views of the GNP and its surroundings at any date (between 1999 and 2010) within the peak of the wet and dry seasons were collected. These two seasons were defined based on historical precipitation data collected over a period of 40 years in the GNP and the peripheries. The period November through to April was considered as wet since on average 98% of the annual rainfall in Zimbabwe occurs during this period (Chamaille´ -Jammes et al., 2007(a), whereas the period May to October was considered dry. We sampled images obtained between

March and April to represent the wet season, whereas images taken in October were sampled to represent the dry season. No single Landsat image scene can give a complete coverage of GNP and its surroundings. As a result, two image scenes were used i.e. World Reference System (WRS) path 168 and row 075 and WRS path 169 and row 075. Landsat images have a temporal resolution of 16 days at a spatial resolution of 30m and are also obtained freely from the United States Geological Survey (USGS) website, http://www.glovis.usgs.gov/. The temporal resolution of Landsat images offers the possibility to choose the date when water availability can be detected. These images were already geometrically and atmospherically corrected. To save disk space, all images were clipped to the study area before processing.

In order to map open water sources both inside GNP and in the surrounding areas, the Modified Normalized Difference Water Index (MNDWI) was calculated from the visible green light and the Middle Infrared radiation (MIR). It is calculated using the formula:(Green-MIR)/ (Green +MIR), Equation 1 where the green band is between 0.525-0.605μ, and the MIR is between 0.75-0.90μ.The design of this water index is based on the fact that the spectral response of water is more sensitive in MIR than in the NIR. This arithmetic operation not only enhances the spectral signals of water by contrasting the reflectance between different wavelengths, but also cancels out most of the 'noise' components that are common in different wavelength regions such as sensor calibration and changing radiation conditions caused by illumination, soil, topography, and atmospheric conditions (Valerie, 2009; Wang et al., 2011). We then determined a threshold to discriminate water from non water land cover types. Thresholding was determined using the segmentation approach (Brakenridge and Anderson, 2006). Furthermore, the threshold was also determined in such a way that it was in agreement with our ground validated points. In this regard, a threshold of 0.09 was applied to extract open water sources such that the cover type is water if MNDWI >0 and it is non-water if MNDWI is = or <0 (McFeeters, 1996).

2.3 Accuracy Assessment

In order to test the mapping accuracy using the MNDWI index, we did a stratified random ampling in the Southern part of GNP and the surrounding agricultural areas of 30 known seasonal and permanent open water sources which included natural pans, dams and river pools as ground validation points (Table 1). Permanent water sources contain water throughout the year whereas seasonal water points have water only during the wet season under normal rainfall years(Torrence, 1981). However, when above normal rainfall is received, such seasonal pans may contain water throughout the year. One of the most important feature of the SELZ are water pans which are

natural sinks occupying depressions formed by deflation on clayey soils (Hitchcock, 1996). These water sources are located in different land uses such as in protected areas and in agricultural areas. The surface area of water points in this study ranged from a minimum of 100m² to a maximum 1000000m² (1km²). Another set of 30 non water points was also selected using stratified random sampling within different land uses as ground validation points. We tested the accuracy of our classification using a confusion matrix. A confusion matrix (Hixson et al., 1980; Lewis, 2001) contains information about actual and predicted classifications done by a classification system. The accuracy measure is based on the Kappa statistic (Lewis, 2001). It has been suggested that an acceptable Kappa statistic accuracy limit for land cover maps derived from classification of satellite data should be above 85% (Lacaux, 2007, Lewis, 2001, Michelson et al., 2000).

The availability of water in water points selected for ground validation both inside and outside GNP was confirmed through observing whether water was present or not during field surveys using a hand held Geographic Positioning System receiver. Two visits were conducted each year during the peak of the wet season (between March and April) and two visits in October during the peak of the dry season. These visits were conducted for three successive years 2009-2011.The validation results are presented in table 1. Mwita et al (2013) suggested that in order to get sufficient detail, Landsat imagery should be combined with high resolution images and field surveys. Thus water points mapped using MNDWI for 17 March 2010 were also overlaid on high spatial resolution images made available through Google Earth obtained fromhttp://www.earth.google.com on 23 March 2010 .Google Earth provides a mosaic of images of different origin, resolutions and acquisition dates which turns Google Earth into a useful decision support tool(El-Asmar and Hereher, 2011). In this case we used the Spot imagery obtained from google earth (23 March 2010) with a high spatial resolution of 5 meters to validate the accuracy of the remotely sensed water points obtained from the Landsat TM images using the MNDWI.

Table 1: Water sources visited for validation purposes between 2009-2011. Water presence/absence was validated twice per year for the wet seasons between March and April while for the dry seasons validation was also conducted twice per year in October.

Water source	Location	Land tenure	Water system	Wet season	Dry season	Water Source	Location	Land Tenure	Water System	Wet Season	Dry Season
Manjinji pan	x-335659 y-7554056	PA	Pan			Gorwana pan	x-362095 y-7567549	PA	Pan		
Masukwe dam	x-327076 y-7589578	AA/PA	Dam			Mawange dam	x-327226 y-7589585	AA/PA	Dam		
Gonakudzingwa pools	x-336069 y-7564368	AA	Mwenezi river			Soshongan pan	x-363758 y-7568890	PA	Pan		
Bossman pool	x-337336 y-7560599	PA	Mwenezi river			Nyamugwe pans	x-374865 y-7575512	PA	Pan		
Manjinjana pools	x-336168 y-7553853	AA	Mwenezi river			Mafuku pan	x-378852 y-7586128	PA	Pan		
Chikombedzi dam	x-392090 y-7599016	AA	Dam			Maguni pan	x-379985 y-7584986	PA	Pan		
Malipati dam	x-33765 y-755976	AA/PA	Mwenezi river			Makonde pan	x-381848 y-7586052	PA	Pan		
Malipati causeway pools	x-337241 y-7558708	AA/PA	Mwenezi river			Pahlela pan	x-382036 y-7586785	AA	Pan		
Mabalauta pools	x-378609 y-7583847	PA	Mwenezi river			Chitanga pan	x-383062 y-7600063	PA	Pan		
Wright's tower pool	x-340184 y-7564368	PA	Mwenezi river			Chefu pan	x-385471 y-7600335	PA	Pan		
Manyandanyana pan	x-390461 y-7675645	PA	Pan			Guluene pan	x-394394 y-7594824	PA	Pan		
Nyala	x-387240 y-7670987	NP	Pan			Sokwe pans	x-395074 y-7595042	PA	Pan		
Gorwe pan	x-361357 y-7563606	PA	Pan			Centre pan	x-395060 y-7595281	PA	Pan		
Nyavasikana pools	x-336069 y-7564368	AA	Maose river			Lion pan	x-394084 y-7596128	PA	Pan		
Magangeni pan	x-334863 y-7556124	AA	Pan			Manyanda pan	x-347003 y-7565102	PA	Pan		

Key: Water source dry

Water present

PA-Protected area
AA-Agricultural Areas

Rainfall Data

In order to test further the accuracy of the remotely sensed water points data derived over eleven year period, it was important to test whether there was any relationship between rainfall patterns in the study area over eleven years and the water points mapped using the MNDWI index. This is because surface water availability in the study area largely depends on rainfall. We expected a weak

relationship in the event that the MNDWI used in this study was less effective in differentiating water from other land cover types.

To achieve this, historical rainfall data for the past eleven years (1999-2010) was obtained from four stations within the study area, i.e. Malilangwe Conservancy, Chipinda pools, Mabalauta station and Buffalo range. These four stations recorded rainfall data for all the eleven years of the study period. For each year, we added rainfall figures for each month to get the total annual rainfall.

Relating remotely sensed surface water point data with rainfall data

In order to test whether rainfall significantly predicts the number of water points we followed a number of steps. Firstly, we removed water points along the rivers mainly because rivers get some of their waters from a wider catchment which is not measured by the rain gauges in the study area. For example, Runde River and Mwenezi river catchments begin more than 100km upstream of the study area. Thus, the water point data that we used to test whether rainfall significantly predicts surface water was based on water pans which receive their water from rainfall that directly fall in the study area. Secondly, remotely sensed surface water data and rainfall from 1999-2010 was used to test whether rainfall significantly predicts the number of water points while remotely sensed surface water data and rainfall data of 1986, 1987, 1988, 1989 and 1995 were used as test data. Next, we tested the data for normality using the Kolmogorov-Smirnov test and found that the data did not significantly deviate from a normal distribution ($P > 0.05$). In this case we adopted parametric tests. Thirdly, we used scatter plots to explore the nature of the relationship between rainfall and the number of water points. Based on the results of the exploratory scatter plots, we fitted a logistic regression function to test whether there is a significant relationship between the amount of rainfall received in the study area and the number of water points mapped during the wet and dry season using a remote sensing index (MNDWI). Lastly, we tested the predictive power of the rainfall-surface water point regression model developed using the 1999-2010 data, using an independent rainfall data set 1986,1987,1988,1989 and 1995. The years 1986, 1987, 1988, 1989 and 1995 were selected in this study because both rainfall and remote sensing data for these years is available. Specifically, we used the logistic regression model to predict the distribution of water points for the same period and then used remotely sensed number of water points in these particular years to test whether the remotely sensed number of water points significantly differed from those predicted by the model. The accuracy of our regression model to predict the number of water points was tested using a z-proportions test (Rodger et al., 2007) and the Root Mean Square Error

(RMSE) calculation for the predicted and actual number of water points. A low RMSE is interpreted as a higher accuracy than a high RMSE.

GIS analysis of spatial and temporal dynamics in surface water points

We selected two years with the most extreme rainfall amounts (minimum and maximum during the period under consideration) in order to provide information on the range of water availability situations that might be experienced in GNP and the surroundings(Figure 2).

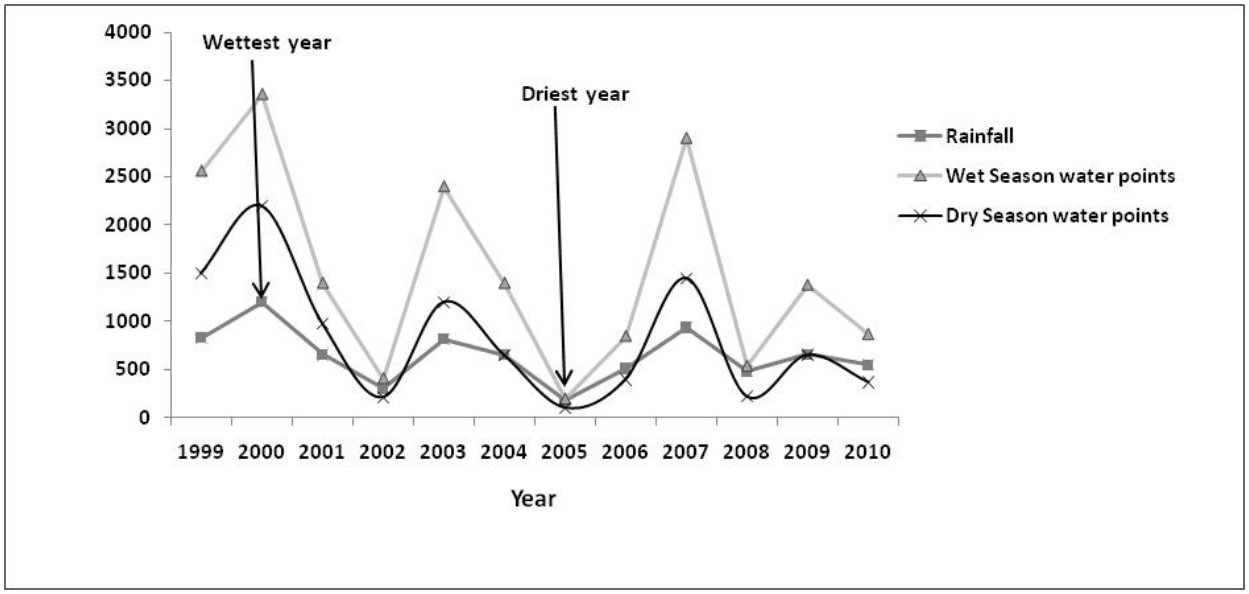

Figure 1: **Rainfall and water points variations between 1999 and 2010 showing the wettest year (2000) and the driest year (2005).**

To achieve this, the locations of all the surface water sources remotely sensed using MNDWI during the wet and dry seasons of the two contrasting years were buffered in concentric 5 km rings and clipped to the study area boundary to find the proportion of area at different distances to water in different land uses. The 5km buffer was chosen because it has been proposed as the typical daily movement range of water dependent small to medium sized herbivores such as impala (*Aepyceros melampus*), warthog (*Raphicerus campestris*) and waterbuck (*Kobus ellipsiprymnus*) (Owen-Smith, 1996). The other distance categories above 10km were also considered because larger herbivores such as buffalo (*Syncerus caffer*), elephant (*Loxodonta africana*) and cattle are capable of moving greater distances (Owen-Smith, 1996; Redfern, 2003). In addition, these distance ranges allow for comparisons with other studies (Redfern, 2005, Redfern, 2003, Western, 1975). We then used the proportion of area in each class of distance to water to compare surface water availability patterns in the GNP and its peripheries between the wet and dry seasons of two contrasted rainfall scenarios over a period of ten years.

RESULTS

The number of remotely sensed surface water points are significantly positively related (r^2 =98% P < 0.01, d.f.=11) with rainfall in the wet seasons. Rainfall explains 98 % and 96% of the variance in the number of surface water points in the wet season and dry seasons respectively. (Figure 3)

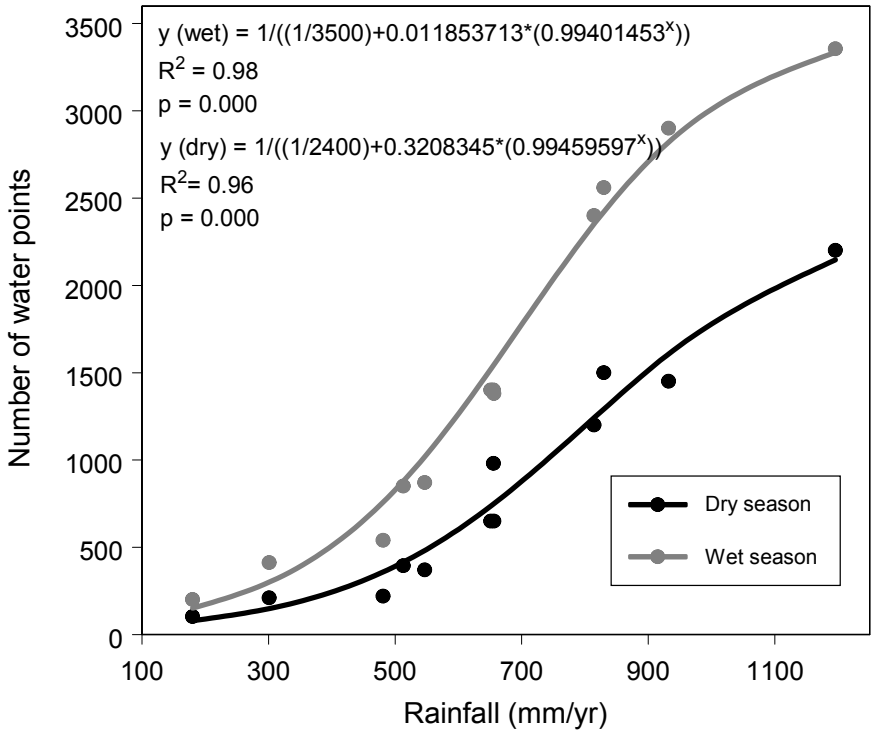

Figure 3: Annual rainfall (mm) and estimated number of water points in Gonarezhou NP and adjacent agricultural areas during the wet and dry seasons (1999-2010).

During model fitting using an independent test data, we observed a $RMSE_r$ of 3.31% and 4.21% for predicting water points in the GNP and the surrounding areas in the wet and dry seasons respectively using rainfall data. The z –test of proportions also shows no statistically significant differences between remotely sensed water points and the predicted estimates based on the model developed (χ^2= 18.5024, d.f.= 4, p> 0.05).

The number and distribution of surface water points in the GNP and the surrounding areas vary according to the amount of annual rainfall received. During the wettest year (2000), 1550 pans were observed across the whole study area during the wet season while only 328 pools were observed along major rivers for the dry season of the driest year (2005)(Figures 4and 5). In addition, in 2005, 90% of the pools identified in the dry season were located inside GNP and the remaining 10% in the communal lands creating a water gradient along the two land uses.

During the 2005 dry season, all natural pans dried up (Figure 5a). Three main river systems were observed during the wet season and these rivers cut across different land uses (Figures 4 and 5). The total length of the three water courses inside the GNP which comprise of 52% of the study area is 340 km while the total length in the surrounding agricultural areas is 458km.

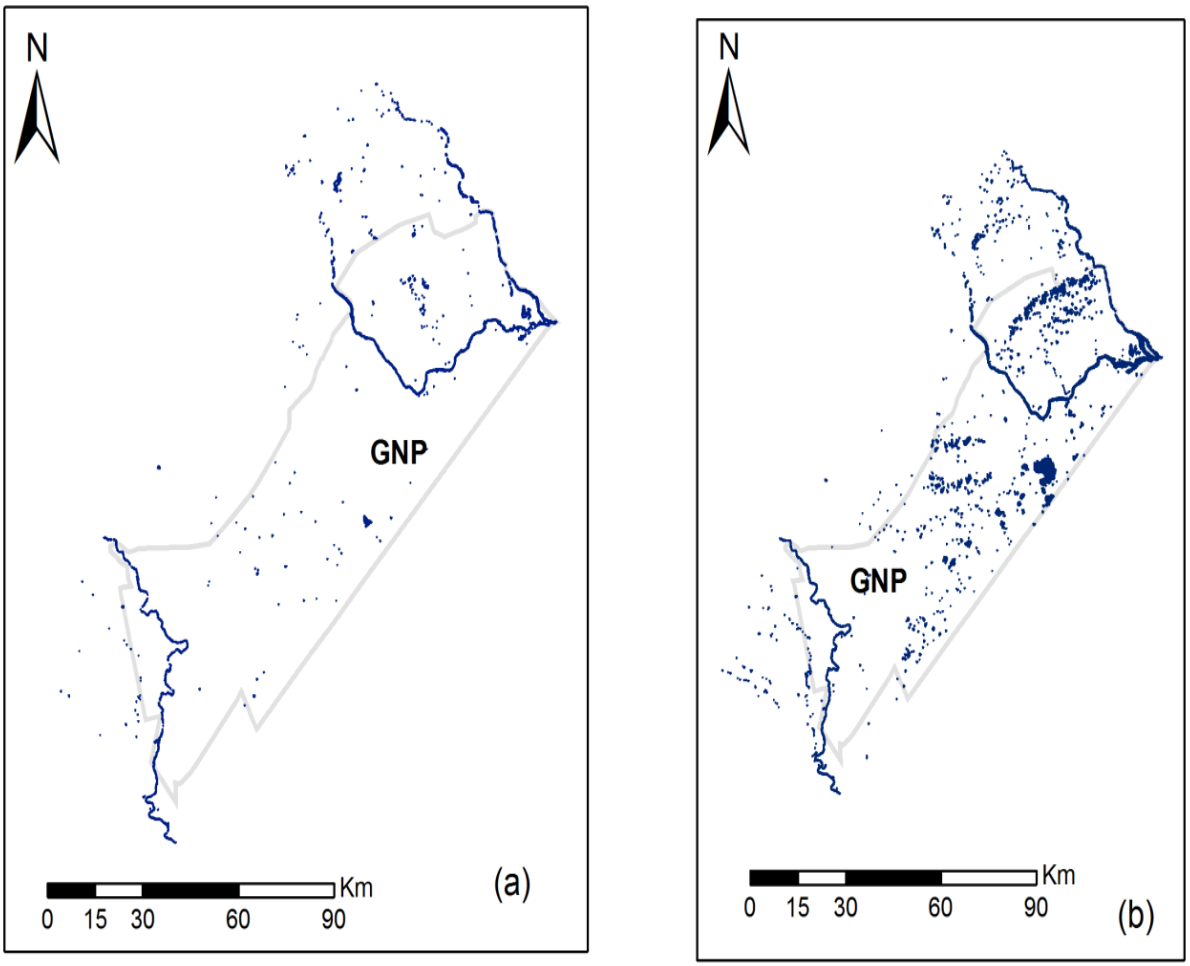

Figure 4:Water distribution during the wettest year(2000) for (a)dry season(b)wet season mapped using MNDWI.

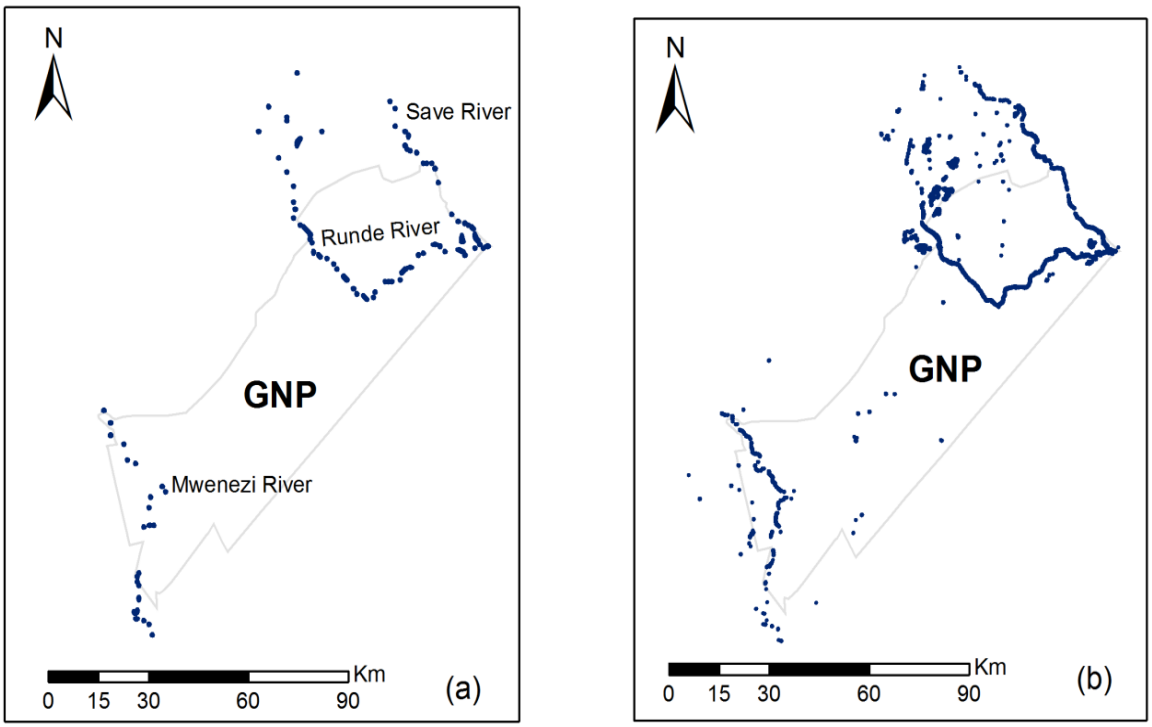

Figure 5:Water distribution during the driest year(2005) for (a)dry season(b)wet season mapped using MNDWI.

During the wettest year (2000) of the study period 96% of the area occurred within 5km to the nearest water source during the wet season (Figure 6). No area inside the GNP was more than 10km to the nearest water source during this period. However, some areas in the surrounding agricultural areas were more than 10km to the nearest water source during this period (Figure 7).

During the driest year (2005) the area lying furthest to water sources increases drastically. Only 41% of the area was located within 5km to the nearest water source during the dry season while 59% occurred more than 5km to the nearest water source(Figure:7). This situation was obtaining for both the GNP area and the surrounding agricultural areas.

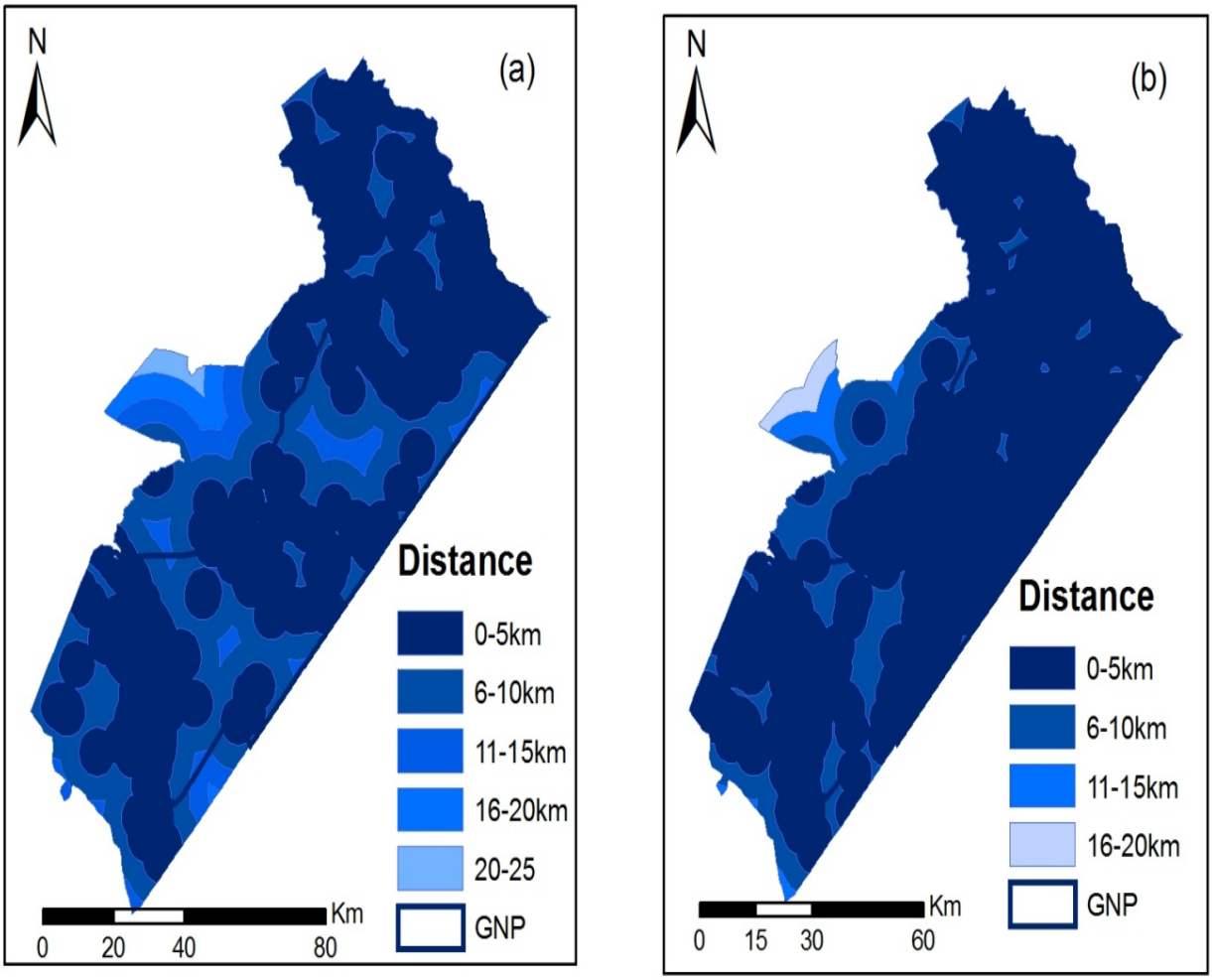

Figure 6: The buffer framework showing distribution of distance to water classes for the wettest year (2000) for (a) the dry season and (b) the wet season.

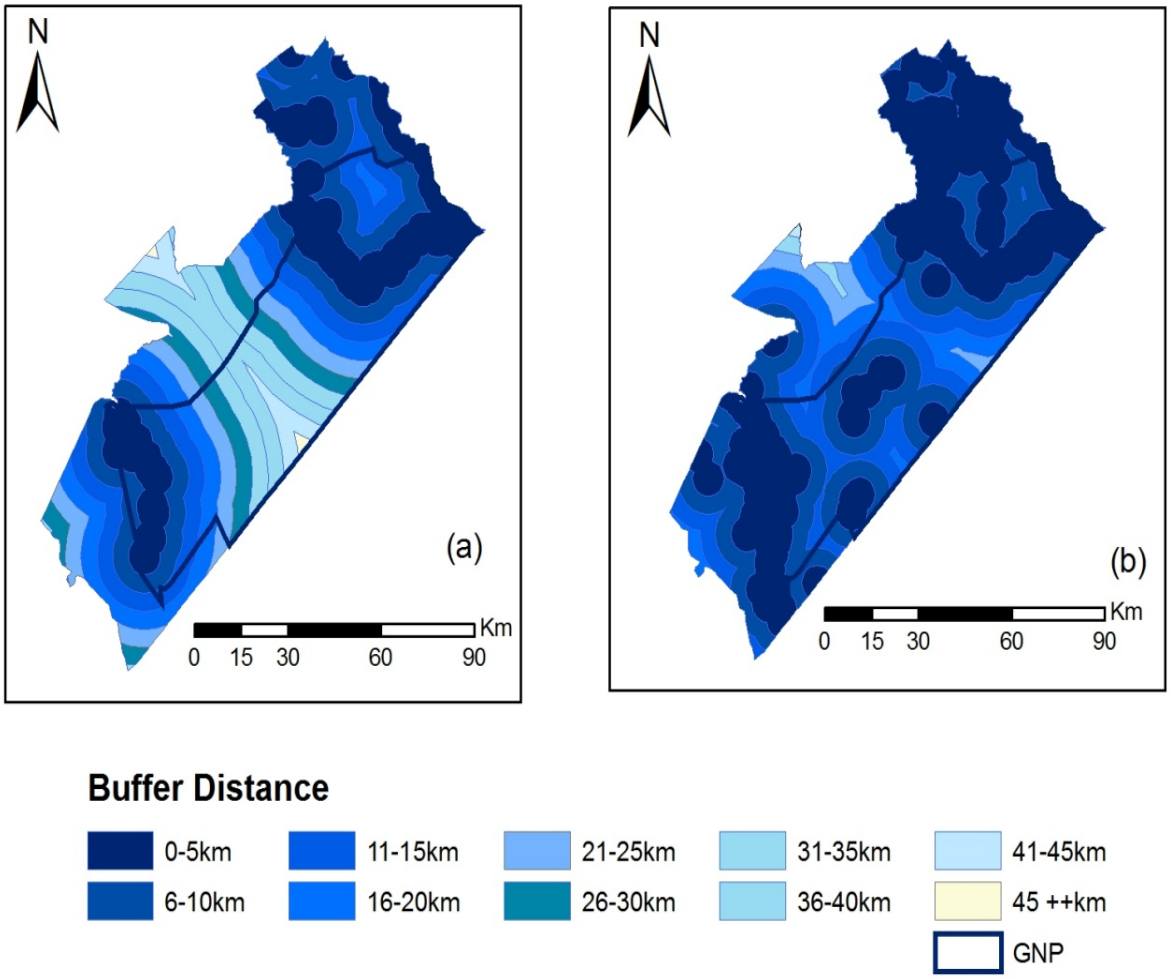

Figure 7:The buffer framework showing distribution of distance to water classes for the driest year (2005) for (a) the dry season and (b) the wet season.

There was a significant difference in the proportion of area lying at all the distance categories under contrasting rainfall regimes except 11-15km distance category (x-squared=232.9009, $p<0.05$) (Figure 8).

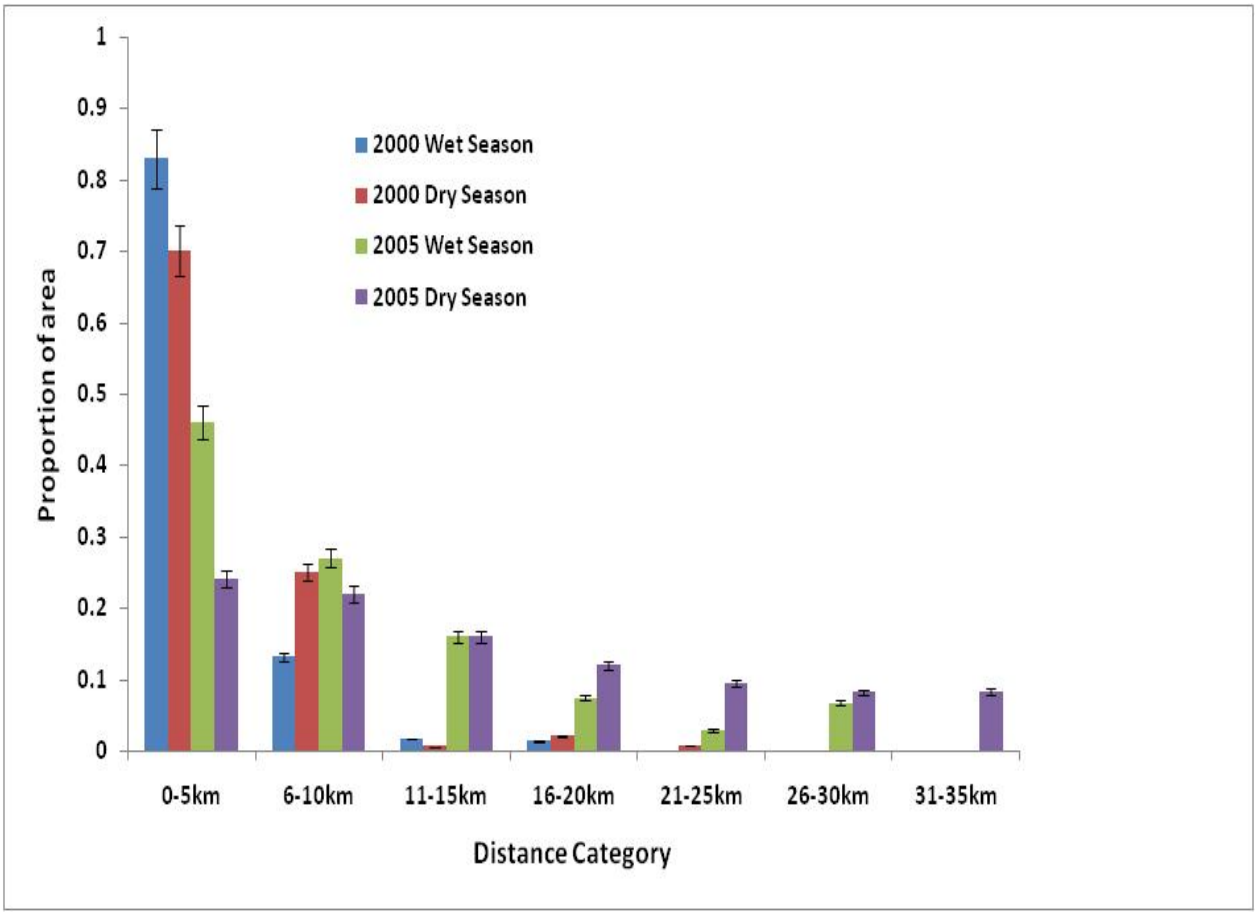

Figure 8: Proportion of area within different distance ranges for 2000 and 2005 wet and dry seasons.

We also observe that the dry season of the wettest year had a higher surface water availability compared to the wet season of the driest year. This is evidenced by the fact that during the dry season of the wettest year, no area was more than 25km away from the water source whereas during the wet season of the driest year the furthest area was 35km from the nearest water source (Figures 6 and 7).

A Kappa Statistics of 94% was recorded when the mapped water points were assessed for accuracy using sampled validated data. Furthermore, based on SPOT 2.5 m imagery made available on Google Earth (23 March 2010), we were able to validate 96% of selected open water sources captured using MNDWI (Figure 9).

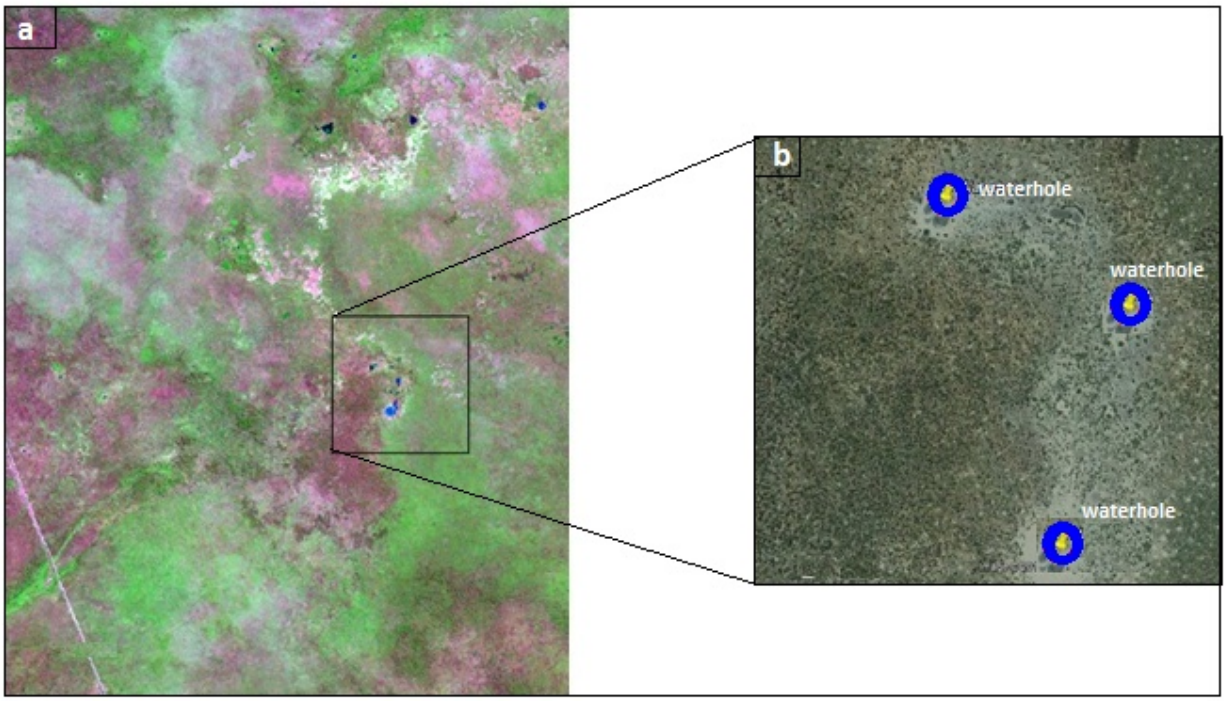

Figure 9: Water points mapped using MNDWI from Landsat image (a) on 17 April 2010 which were validated using images made available from Google Earth (b) for 23 April 2010.Location: 21° 40' S and 31°40'E

DISCUSSION

Results of this study indicate a strong positive relationship between wet season rainfall and number of water points (r^2= 0.98, p<0.01 for the wet season and r^2=96, p<0.01 for the dry season). This not only indicates the utility of remote sensing, particularly the MNDWI in mapping water points, but also clearly indicates that rainfall is a significant predictor of available surface water in semi-arid environments. Furthermore, our remote sensing-rainfall model predicted the number of water points for five different test years, with a low RMSEof 3.31% and 4.21% for the wet and dry seasons respectively. The relatively low RMSE, as well as the close prediction of the model suggest that the regression model developed here using remotely sensed and rainfall data can be used to estimate surface water availability in similar semi arid environments with similar conditions where field data may not be available or are scarce.

Results on the spatial analysis of available surface water points indicate that during the wettest year (2000) 96% of both the protected area and the agricultural areas had a water point within 5 kilometers, which may be considered as threshold distance within which water dependant herbivores will range (Owen-Smith, 1996). During the driest year, however, only 41% of the study area had a water point within 5km. This indicates that an increase in rainfall results in water

resources being available at shorter distances to each other. This result is typical of semi-arid environments where the available surface water is closely related to rainfall, at least in the short term except where ground water is close to the surface (Chamaillé-Jammes et al., 2007).

Our results also show that most of the remaining water sources during the dry season were mainly concentrated along the major rivers which had a high probability of retaining water even during such dry conditions. This could be explained by the fact that these rivers have larger catchment areas which tend to collect large amounts of water over larger areas and thus retain moisture longer than pans. On the other hand, results indicate that rainfall fed pans are more sensitive to rainfall fluctuations as they usually dry out in the dry season between May and November (Table 1), while only persisting when above normal rainfall is received (Figure 4a). The sensitivity of pans to rainfall fluctuations observed in this study is consistent with finding in Hwange National Park, which has similar climatic conditions to the SELZ (Chammaille-James et al 2007a).

In this study results indicate that annual rainfall can be used to predict surface water availability. While several studies have provided a snapshot of water distribution in arid and semi arid environments (McFeeters, 1996, Verdin, 1996, Valerie, 2009, Daniel et al., 2011, Ding, 2011), the changes in the distribution patterns of surface water sources in space and time have rarely been documented. Here, through a regression model that combines remotely sensed surface water and rainfall data, our study has provided an approach which allows rangeland managers not only to detect, map, and monitor surface water point distribution with improved accuracy at specified periods, but can even do so when remotely sensed data is not available. However, we have to caution that the application of the rainfall-remotely sensed surface water model developed here may have limited applications in areas of high vegetation cover, as well as in mountainous terrain where effects of shadow may be confused with the water signal.

Furthermore, results indicate a strong water gradient especially in the dry years where for every one waterhole in the agricultural area there are nine waterholes in the protected area. This is evidence that most natural water sources are concentrated inside the protected areas compared to the surrounding agricultural areas. The strength and persistence of this gradient should thus be taken into consideration in order to successfully predict the effects of surface water distribution on wild and domestic herbivore interaction. This is a subject for further study.

CONCLUSION

Based on the results of this study, we make a number of conclusions. Firstly, we conclude that MNDWI can successfully be used to map surface water in semi arid environments. Secondly, we conclude that surface water availability in GNP and the surrounding agricultural areas derived from remotely sensed data is strongly positively related to annual rainfall. Thereafter, we conclude that increases in rainfall lead to water availability occurring within short distances of each other. We also conclude that there is a water gradient from protected areas which tend to have more surface water points to the agricultural areas which also have less water points especially during the dry season. Finally, we conclude that results of our study provide an approach which allows rangeland and park managers to predict changes in surface water distribution based on rainfall data. Findings of this study show that hypotheses concerning herbivore interaction as a function of surface water availability can now be tested. However, we caution that further research is needed to test the model developed in this study in other environments.

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Indigenous Knowledge Farming Systems That Have Contributed to Sustainable Land Management in Ward 11 of Zhombe Communal Lands in the Midlands Province

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ABSTRACT

Zhombe Communal lands of the Midlands Province are under threat from anthropogenic activities (deforestation; overgrazing; monoculture and veld-fires) which have resulted in terrain deformation (gulley erosion) and loss of soil nutrients leading to low crop yields even when rainfall is above average. This has led to the loss of economic productivity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands. This research reveals that in Ward 11 of Zhombe Communal lands traditional skills to manage complex ecological systems have been adopted and implemented. A study was conducted in the area in April 2012. Forty participants were selected using systematic sampling technique. The methods of data collection included questionnaire interviews and observations directed at key participants and pieces of land respectively to solicit information on the use of Indigenous Knowledge Systems in sustainable agricultural land management. The findings indicate that 86 percent of subsistence farmers in the area prefer indigenous knowledge systems in land conservation. Indigenous Knowledge Farming Systems such as intercropping maize with pumpkins, maize with groundnuts, maize with beans and potatoes with onion serves a tripod purpose of maintaining soil fertility through the benefits of crop symbiotic relationship such as nitrogen fixation and weed control; it also minimizes the risk of complete crop failure. Grass strips of land of one to one-and-a-half meters wide, with indigenous vegetation are left between fields to control soil erosion and conserve biodiversity. Fallow system for natural rejuvenation of the land is used including rotational grazing. Mixed farming is practiced which help improve the fertility of the soil by using the manure that comes from the animals. Precision farming, which is identifying parts of the field that have more fertility than others e.g. spots that used to have anthills, cattle kraals or household wastes are selected for intensive planting.

Key Words: indigenous, farming systems, communal, terrain, ecological systems, crop failure.

INTRODUCTION

The demand for food has increased with population growth leading to improvements in farming methods (industrial agriculture), mechanization of work (tractors), the introduction of high-yield-varieties of wheat and other plants (Green Revolution), and the use of pesticides to control crop pests. These measures of improving productivity in the farms have demystified the Malthusian hypothesis that the populations of the world would increase in geometric proportions while the food resources available for them would increase only in arithmetic proportions. However, the land that can be used for agricultural activities remains constant. Of the over 13 billion hectares of land in the world, about 50% is completely unusable for crop production and only about 11% of the total area of the world is arable (Acquaah, 2005). Most of the arable land is located in the United States, Europe, Russia, India, China and Southeast Asia. Shortage of arable land, especially in the tropics has forced people to occupy marginal areas leading to environmental consequences.

The adoption of the Green Revolution in most developing countries to increase food production has necessitated environmental consequences in most cases. Fertilizer, slurry and pesticides contribute to the pollution of the environmental system. Where chemical fertilizer accumulates in lakes and rivers, the water becomes enriched with nutrients (eutrophication) and the ecosystem is greatly disturbed. The Friends of the Earth claim that pesticides are injurious to health especially in developing countries resulting from lack of instruction, fewer safety regulations and faulty equipment. Pesticides are blamed for the rapid decrease in Britain's bee and butterfly populations, and an up to 80 per cent reduction in 800 species of fauna in the Paris basin (Waugh, 2001).

Environmental degradation is a cause for concern in Sub-Saharan Africa. This is exacerbated by a ballooning population in developing countries forcing most small scale farmers to occupy marginal lands and use chemicals to boost agricultural productivity. To curb the loss and impoverishment of the land indigenous knowledge farming systems should be adopted. Inclusion of Indigenous Knowledge has been adopted in various spheres of life such as circumcision to reduce chances of contracting HIV/AIDS, use of both modern and traditional medicines when one is sick, in veterinary services there is also use of ethno-science and also in increasing the amount of precipitation there is cloud seeding and traditional rainmaking.Therefore, it is prudent to adopt Indigenous Knowledge Farming Systems in the conservation of the land environment.

The fascinating aspect of discussing crop-livestock technologies is that one has to think beyond the confines of either crops or livestock alone. In order to understand the issues at stake one has to know details about crops, animals, soils and people - and all the associated details. The technical

issues concern first the intricacies of integration, i.e. the mutual adjustment over time and space of crops and animals (crop rotations, use of crop residues as feed and use of excreta for crops). Secondly, they stimulate the (re-)discovery of techniques that were traditionally in use in many societies, but that have been forgotten because of the emphasis on only crops or animals.

Objectives of the study

i. To show the indigenous farming techniques that contributes to sustainable resource management.
ii. To explain/outline the procedures of the indigenous farming systems that contributes to sustainable management.
iii. To show how the indigenous knowledge farming systems can be integrated with the scientific methods for sustainable resource management.
iv. To come up with awareness measures that can be taken to motivate more communal farmers to adopt some of the indigenous farming systems for sustainable resources management.

Study location

The study is located in Ward 11 of Zhombe Communal area (Figure 1) in the Midlands province which lies in agro-ecological region four. This region is characterized by average rainfall of 650mm per year and temperatures ranging from 24-28 degrees Celsius. These climatic conditions necessitate sustainable resource management due to a relative fragile environment.

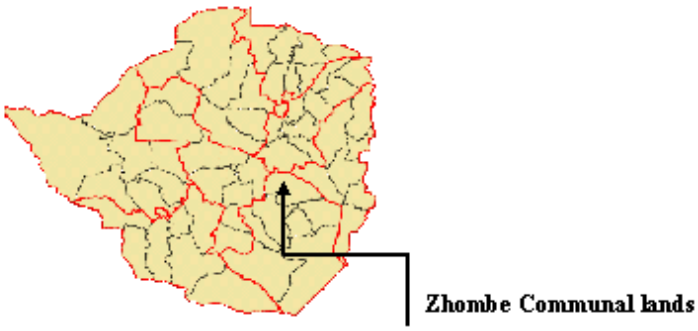

Figure 1: Map showing the location of Zhombe Communal Lands

METHODOLOGY

A multi-methods approach was used in this research that included the use of questionnaires, interviews and field observations. Questionnaires were directed at the subsistence farmers of Ward 11 to obtain information on the effectiveness of indigenous knowledge farming systems in sustainable land management. Observation of the quality of plants in terms of size, colour and productivity; diversity of natural vegetation and areas experiencing soil erosion was also done. The farmers were also interviewed to explain some of the indigenous knowledge farming techniques.

A total of 40 subsistence farmers participated in this research which is 58% of the Ward 11 population. Systematic random sampling was done in ward 11 in order to minimize bias. Farmers were interviewed in their households and they also visited the fields with the researcher to clarify some of the farming techniques. There was a proactive attempt to get a balanced participation of males and females in the study since women are also actively involved in farming, especially in the growing of food crops such as groundnuts, cowpeas and sweet-potatoes. However, partly because of the dominantly patriarchal structure of those communities, in the end there were 9 (23%) female and 31(77%) male participants. The questionnaire instrument is shown in appendix 1 at the end of this paper.

LITERATURE REVIEW

As early as 1987 the World Commission on Environment and Development advised that indigenous communities were "repositories of accumulations of traditional knowledge and experience" and the larger society could learn from traditional skills to manage complex ecological systems (Larson, 1998). Therefore, communities should embrace culture and history in addressing today's pressing environmental issues. This means that indigenous knowledge is of value in environmental conservation. Larson (1998) defines indigenous knowledge as the knowledge used by local people to make a living in a particular environment. Indigenous knowledge is the sum total of the knowledge and skills which people in a particular geographic area possess and which enable them to get the most out of their environment (Briggs, 2005). Most of these knowledge and skills have been passed from earlier generations.

Indigenous knowledge systems are a key element in the development of poor communities and provide "culture-fit" problem-solving strategies for a diversity of situations Dube and Musi, 2002). This implies that for any given project to succeed local people should be consulted right from the

start and their own knowledge systems should be incorporated into the process. Indigenous knowledge complements, rather than compete with, global knowledge systems in the implementation of projects. Indigenous knowledge is also referred to as "local knowledge," "traditional knowledge," "indigenous traditional knowledge," "rural knowledge," "traditional ecological knowledge," and so forth.

Indigenous knowledge is specific to communities. However, in most cases indigenous knowledge exists only in theory, people speak about it but do not have any practical experience of it. Briggs (2005) asserts that traditional practices have not been used and people have become alienated from resources since colonial days, so it is very difficult to translate the stories into action. Communities should fully embrace this knowledge because it sustains the community and its culture and maintains genetic resources necessary for the continued survival of the community. In the Eastern Ghats of India, for example, they conserve the species and surroundings of their clan totem, such as the peacock or the barking deer (Menchu, 2007). The indigenous techniques used in cropping and animal husbandry are living examples of sustainable agriculture (ibid).

Indigenous Knowledge Farming Systems

The challenges of crop production in tropical regions are that the soils are highly leached, acidic and low in nutrients (Dupriez and De Leener, 2003). This means that every plant exploits a particular soil layer by taking from it all the nutrients it requires. During the process of harvesting, the farmer removes the agricultural the produce containing the nutrients extracted from the soil. The soil layer exploited by the cultivated plants is impoverished by the harvesting of crops. However, they can be made productive through the application of chemical fertilizers. Unfortunately, producers in most communal areas can ill-afford these production inputs. For them to maintain high productivity in their farms they have to use what is locally available, that is organic matter. This, therefore, means that they should make use of indigenous knowledge farming systems.

RESULTS

The results of this research show that indigenous knowledge farming techniques still play an important role in sustainable land conservation in the area. The majority of the farmers (86%) depend on these farming techniques and the remaining 14% highly value the use of chemicals in their fields to increase their productivity

The findings indicate that both men and women are involved in agricultural activities but men constitute a bigger percentage (77.5%) compared to females (22.5%) as shown in Table 2 below.

Table 2: Proportions of males and females

	Frequency	Percent	Valid Percent	Cumulative Percent
Female	9	22.5	22.5	22.5
Male	31	77.5	77.5	100.0
Total	40	100.0	100.0	

Table 3: Ages of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	21-30	5	12.5	12.5	12.5
	31-40	9	22.5	22.5	35.0
	41-50	12	30.0	30.0	65.0
	51-60	7	17.5	17.5	82.5
	61-70	3	7.5	7.5	90.0
	71+	4	10.0	10.0	100.0
	Total	40	100.0	100.0	

The findings indicate that the modal class is 41-50 years. Most of the respondents are economically active and were aged between 41 and 50 years. The distribution is bell-shaped. The least number of respondents were aged between 61-70 years.

Table 4

Education levels of respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Primary	11	27.5	27.5	27.5
O-level	24	60.0	60.0	87.5
A-level	2	5.0	5.0	92.5
College	3	7.5	7.5	100.0
Total	40	100.0	100.0	

All the respondents were literate. They could read and write. Most of the respondents had O-level (60%) and the lowest had A-level (7.5%). The findings also indicate that out of the 40 respondents 26 (65%) were full time communal farmers and 14 (35%) were employed.

All the respondents (100%) had hand hoes, 77.5% had ox-drawn ploughs, 57.5% had harrows and 7.5% had tractors. This indicates that simple tools such as hand hoes are easily accessible to all the farmers and the most expensive implements such as tractors are inaccessible to the farmers in communal areas

Mixed farming

Table 5: Number of farmers who practice mixed farming

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	31	77.5	77.5	77.5
No	9	22.5	22.5	100.0
Total	40	100.0	100.0	

Table 5 shows that very large percentage (77.5%) of the participants practice mixed farming. These are the farmers that have livestock (cattle, goats and sheep) and use manure to improve soil fertility in their fields.

Mixed farming is the growing of crops and keeping of livestock on the same farm, which helps to improve the fertility of the soil by using manure that comes from the animals. The research found that most livestock products in mixed farming systems are derived from animals that are fed on local resources such as pasture, crop residues, fodder trees and shrubs. The exchange of these resources contributes to soil texture and fertility. Crop residues can be used for animal feed as well as for soil fertility. The fibrous crop residues have a potential in soil conservation through mulching. Stover refers to the dried stalks and leaves of a field crop used as animal fodder after the grain has been harvested. Integration of crops and livestock is often considered as a step towards sustainable agricultural production because of the associated intensified organic matter and nutrient cycling.

Plate 1: Stover storage **Plate 2: The use of night kraals**

It is believed that leaving the crop residues in the field causes a loss of nutritive quality and sometimes leaching of nutrients through rains and degradation processes that involve fungi. The stover storage is put in kraals where animals are fed, normally at night, and this adds the amount of manure. In various systems draught oxen, and small ruminants (goats and sheep) are kept overnight in pens in the compound throughout the year, and the manure they produce is transported to the fields during the dry season. Manure from small ruminants takes longer to have an effect on crop yields than cow dung, but once it has started the effect lasts for several years. The dung is mixed with biomass, i.e. with straws, leftover feeds, dry leaves and grass. This leads to the formation of a lot of manure. It was observed that in most of the house-holds weeds from the fields were taken to the kraals to add manure. Of the 31 participants who practice mixed farming 90% said it is highly effective and 10% said it is effective. They explained that mixed farming depends on the number of livestock one has. If the numbers of livestock are less this leads to less manure and it reduces the effectiveness of mixed farming.

Plate 3: Use of organic manure

The picture above shows heaps of manure that have been transported from the kraal to the field. Smith (2006) states that dung and urine from livestock contain several nutrients such as nitrogen, phosphorus and potassium, and the solid fraction contains organic matter that is important to maintain soil structure and fertility.

- Nitrogen is essential for growth, for making the stems, leaves and roots; it is an important component of proteins.
- Phosphorus is needed for the plants to flower, to bear fruits and to develop strong roots.
- Potassium is important for tuber and fruit enlargement while it helps to maintain the healthy activity of all plant tissues.

Household waste and compost

Table 6: Number of participants who use compost manure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	12	30.0	30.0	30.0
	No	28	70.0	70.0	100.0
	Total	40	100.0	100.0	

Table 6 shows that 12 participants use compost manure and the remaining participants donot use it. Only 30% percent of the participants use compost manure because it only covers a small portion of the field.

Plate 4: Compost pit filled with organic waste in the process of decomposition

Composting is a process to break down the organic materials to make the nutrients in the biomass accessible to plants. The participants indicated that compost is normally produced from a mixture of all kinds of organic waste, including crop residues and household waste. The technology is very ancient and there are many different ways to compost organic materials. Good compost is composed of green materials – leaves and soft stems – as well as thin branches and chopped straw. Household waste consists of partially decomposed waste from a variety of origins. It takes 4 to 6 months for compost to become mature, or ripe, for use. It plays no part in fertility management where land is abundant since it is produced in smaller quantities. However, farmers are prepared to work hard to retain nutrients on their soil when land for cultivation becomes scarce and when food demands increase. For example, farmers in Zhombe, said they apply household waste, combining it with cow dung and the droppings of small ruminants. It was observed that only biodegradable solid waste such as sadza, vegetables and cop residues is used to make these composts. Of the 12 participants who use compost manure 17% said it's highly effective, 66% said its effective and 17% were neutral. Compost manure is not favoured by most of the farmers because it does not cover large areas of the field and it should be prepared every year.

'Gatshopo' or conservation tillage

Table 7: Number of farmers who practice 'gatshopo'

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	23	57.5	57.5	57.5
	No	17	42.5	42.5	100.0
	Total	40	100.0	100.0	

The results indicate that 57.5% of the participants use zero tillage which is popularly known as "gatshopo" in the area. Those who use it argued that the major reason for practicing zero tillage is to reduce soil erosion which eventually leads to land degradation.

Plate 5: A woman fertilizing a crop field with great care and precision using manure

The participants who use zero tillage highlighted the following steps to be followed in zero tillage:

- In "Gatshopo" the farmer does not use a plough; he/she does not need draft power to prepare the fields. The farmer does not disturb or compact the soil's natural structure. He/she digs precise planting holes using a hand hoe in a uniform pattern throughout the field and put manure in those holes.

- Plant residues are used as mulch to keep the moisture in the soil and to protect the soil from being washed away. The farmer never burns vegetation that covers the soil. He/she slashes or cuts the plants and previous stover, which will spread more evenly over the soil. A thick layer of mulch retains soil moisture and prevents overheating. It decays slowly and is changed into humus.
- The farmer plans out the field and measure where each planting hole will be for an optimal distribution.
- The farmer does not wastefully broadcast seed and manure on to the soil as this will likely result in poor seed-soil contact, wasted fertility and ultimately lowered yields. Manure is put in individual holes.
- Planting in early- to mid-November, or immediately following the first effective rains of the season to ensure even germination and maximize on the use of water. The farmer maintains a disciplined and regular weed control. Weeds take moisture that should be available to the crops.

It is believed that a 20% residue cover can reduce soil erosion by 50% (Waugh, 2001). No-till planting systems leave the most residues on the soil surface. In such cases, soil erosion can be reduced by 90 to 95% of what occurs in conventional tillage. 23 participants use this method and 83% said it is highly effective, 9% said it is effective, 4% said it is neutral and 4% said it is less effective, though the participants said the farming system is labour intensive.

Fallow system ("Ukulaluka")

Table 8: Number of farmers who practice fallow system

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	32	80.0	80.0	80.0
	Yes	8	20.0	20.0	100.0
	Total	40	100.0	100.0	

Twenty per cent of the participants use the fallow system. These are the farmers who have several fields in the area and they can afford to leave some to lie fallow for three to four years.

Plate 6: Land under fallow system covered by indigenous grass and trees

In the past fallow was the main technique to restore soil fertility, because there was more than enough land available. Farmers in Zhombe who have more land tend to depend on fallow as the technique for restoring the natural soil fertility lost through cultivation. This is possible because there is plenty of agricultural land available and entire fields can be left fallow for periods of three to five years. The grass is used as fodder if animals are present on the farm especially during the winter season. The fallow system increases the amount of humus on fields for the benefit of cultivated crops. It was observed that all kinds of vegetation ('umlaluka') grow there, for example herbaceous plants, shrubs, trees and creepers.

Respondents stated that nutrients taken up by deep rooting plants are restored to the layers near the surface as the leaves drop and form humus. Turning organic matter into humus is the most important aspect of leaving fallow. Farmers stated that methods limiting the formation of humus must be ruled out, particularly the wanton destruction of organic matter by fire. Fires produce not humus but ashes that are blown away, leaving denuded soil exposed to erosion. All of the participants who practice fallow system said the method is highly effective; however the produce tends to decrease with each harvest if manure is not used.

Intercropping

Table 9: Number of farmers who practice intercropping

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Yes	40	100.0	100.0	100.0

All the respondents (100%) practice intercropping as a land conservation measure and to reduce the chances of total crop failure which might lead to starvation.

Maize and sweet potatoes

Plate 7: Maize intercropped with sweet potatoes

It was observed that maize and sweet-potato are a common intercropping combination in Zhombe. Farmers stated that when planted simultaneously with maize, sweet-potato does not affect maize yield. These were the recommendations for maize-sweet-potato intercropping:

- Use an early maturing variety of maize SC401 (Inkawu/Tsoko) and a shade tolerant variety of sweet-potato
- Plant maize and sweet-potato simultaneously
- Plant at the beginning of the rainy season
- Plant maize in rows 75 cm apart with in-row spacing of 25 cm
- Plant sweet-potato midway between maize rows
- Weeding is especially important at the beginning of the season
- In addition to harvesting maize and sweet-potato, sweet-potato vines may be used as fodder

It was also observed that the ridges for the sweet-potatoes reduce runoff thereby curbing soil erosion. A lot of water is retained and this increases soil moisture for plant use. Farmers also highlighted that maize plants and the dense cover of sweet-potato leaves intercept precipitation thereby reducing the raindrop impact and this protect the soil from raindrop splash erosion.

Plate 8: Intercropping maize with groundnuts

Groundnuts can also be intercropped with maize although this grain legume is often better grown as part of a rotation. One of the main benefits of intercropping is an increase in yield per area of land. Systems that intercrop maize with a legume (groundnuts) are able to reduce the amount of nutrients taken from the soil as compared to a maize mono-crop. When nitrogen fertilizer is added to the

field, intercropped legumes use the inorganic nitrogen instead of fixing nitrogen from the air and thus compete with maize for nitrogen. If the farmer uses nitrogen fertilizer intercropping is not beneficial. However, when nitrogen fertilizer is not applied, intercropped legumes will fix most of their nitrogen from the atmosphere and not compete with maize for nitrogen resources. A one-crop field does not produce enough trash and organic matter to maintain soil fertility.

Plate 9: Intercropping maize with beans

Maize and beans are another popular intercrop. Farmers can benefit from the high protein of the beans as well as the improved soil fertility. Bean plant density had no influence on maize or bean yields, indicating that maize yield is not affected by bean intercropping.

Recommendations for maize-bean intercropping:

- Plant at the beginning of the rainy season (November or December)
- Plant when the soil is saturated
- Plant higher densities of maize (40,000 plants/ha) to maximize the yield and calorie production

If soil nutrient depletion is a problem, it is strongly encouraged to choose an intercropping system including legumes (beans or cowpeas) that obtain nitrogen from the atmosphere rather than taking it from the soil. Leguminous intercrops fix nitrogen in the soil. In addition, the green parts and roots

of intercrops can decompose and release nitrogen into the soil where it may be made available to other crops. In intercropping with appropriate crops; these farmers may benefit from improved soil fertility, healthier diets, increased productivity and reduced risk of total crop failure

Plate 10: Intercropping maize with cowpea and grass strips (forage)

Intercropping of maize and cowpeas is especially beneficial on nitrogen poor soils. As cowpeas obtain the majority of their nitrogen from the atmosphere, they do not compete with maize for nitrogen in the soil. Farmers found that cowpeas planted 3 weeks after maize had significantly reduced yields and therefore recommends planting cowpeas simultaneously with maize.

As many small farmers value their leisure time, they may prefer to plant one maize and one cowpea seed in each hole rather than planting alternate rows of maize and cowpeas. This will save them time, but slightly reduce potential yield and monetary return.

Deep roots of maize plants penetrate far into the soil breaking up hardpans and use moisture and nutrients from deeper down in the soil. Shallow of cowpeas roots bind the soil at the surface and thereby help to reduce erosion. Shallow roots also help to aerate the soil. When two or more crops are grown in sequence in the same field, each crop uses up the fertility of the soil in its own particular way. Different plants grow to different depths and use up different nutrients.

The addition of cowpeas to the maize field provides an important protein supply for human and livestock consumption, improves soil fertility and structure, suppresses weeds, and insures against total crop failure when one crop fails. The cowpea is an indigenous knowledge drought-resistant

crop used for survival. The results show that 88% participants said intercropping is highly effective and 12% said it is effective. Farmers favour this system because of its several advantages.

Use of grass and tree strips (forage)

Table 10: Number of farmers who use grass and tree strips between fields

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	36	90.0	90.0	90.0
	no	4	10.0	10.0	100.0
	Total	40	100.0	100.0	

The use of grass strips is common in Zhombe communal lands. Grass strips are pieces of land of approximately 1to 1.5m between fields or between farms. Ninety per cent of the respondents make use of grass and tree strips between their fields to curb soil erosion and to keep forage for their livestock during the winter season. Vegetation strips enhance soil fertility by adding organic matter to the soil through the decomposition of leaves that drop. Trees are deeper feeders than annual crops and hence do not compete for nutrients with the target crop being produced. They are used to control soil erosion and also contribute to the conservation of biodiversity and provide resources for human use, including cattle feed, medicinal plants and handicraft materials. The most common indigenous trees are *Brachystegia boehmii* (itshabela/pfute), *Brachystegia spiciformis* (igonde/musasa), *Berchemia discolor* (umnyi/munyii) and *Combretum apiculatum* (umbhondo/mugodo). Tree leaves are the main source of feed to the livestock in the area towards the onset of the rain season. Animals also feed on grass strips during the winter season. Indigenous grasses in these strips include *Panicum maximum* (uhatshi/chitsetserere), *Heteropogon contortus* (inzala/sina) and *Hyparrhenia dissoluta* (uqunga/dangaruswa) and they are very palatable to animals. Of the 36 participants who use grass and tree strips 83% said it is highly effective, 14% said it is effective and 3% were neutral.

Precision farming or satellite farming

Table 11: Number of farmers who practice precision farming

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	32	80.0	80.0	80.0
	No	8	20.0	20.0	100.0
	Total	40	100.0	100.0	

The results indicate that 80% percent of the respondents practice precision farming. Precision farming is a farming management concept based on observing and responding to intra-field variations. It entails site specific farming. The farmer identifies parts of the field that have more fertility than others, for example spots that used to have anthills, cattle kraals or household wastes are selected for intensive planting since they have high fertility. The findings indicate that out of 32 farmers who practice precision farming 81% said it is highly effective, 9% said its effective, 6% said it is neutral and 4% said it is less effective. Crops in areas which were once kraals and anthills were looking healthier and larger than other plants. However, farmers indicated than this farming method does not lead to high productivity since it concentrate on small pieces of land.

Rotational grazing

Table 12: Number of farmers who practice rotational grazing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	31	77.5	77.5	77.5
	No	9	22.5	22.5	100.0
	Total	40	100.0	100.0	

Table 12 indicate that 77.5% of the farmers practice rotational grazing. These are the farmers who also practice mixed farming.

Plate 11: Cattle from the pastures in the summer season

In Ward 11 of Zhombe communal lands there are three zones that is the areas for settlements, crop cultivation and pastures. During the summer season (December to May) livestock is moved to the pastures where there are lot of trees and grass. The major reasons are to protect the crops in the zone where crops are grown and to conserve grass in these areas for winter season. In the winter season animals are moved to the zone of crop cultivation where they feed on crop residues and forage found between farms and where fallow system is practiced. There will be enough food for animals in the winter season. This rotational grazing acts as a barrier to land degradation. Overgrazing is not experienced since animals are not concentrated in one area throughout the year. The results show that out of 31 farmers who practice rotational grazing 94% said the method is highly effective, 3% said it's effective and 3% were neutral.

Participants were also asked to suggest measures what can be done to improve productivity without compromising the land and their responses are shown in table 13 below.

Table 13: Other farming measures that can be implemented to conserve the land

Possible solutions	Reducing stock numbers	Education farmers	Cattle loaning	Artificial (chemical) fertilizers	Resettlement of people	Growing crops in relation to soil type
Per cent age	**29.3%**	**73.2%**	**14.6%**	**7.3%**	**12.2%**	**14.6%**

The findings indicate that 73.2% of the respondents said farmers should be educated on good farming techniques, 29.3% said stock numbers should be reduced to control overgrazing, 14.6% said farmers should do cattle loaning for other farmers to have access to manure and they also said farmers should know the characteristics of the soil by studying the vegetation that grow in those areas so that they plant their crops in relation to soil type. For example areas with Mopani trees have clay soils which have a poor drainage and they can be affected by water logging when rainfall is in excess and areas with *Combretum apiculatum* (umbhondo/mugodo) have soils of low fertility and they quickly lose moisture. 12.2% of the respondents said people should be resettled to ease pressure on land. The least number (7.3%) of the farmers said artificial (chemical) fertilizer should be used to improve productivity. They argued that what is important is the amount of produce one gets from the land.

CONCLUSIONS

Literature reviewed shows that indigenous knowledge farming systems have been practiced globally since time immemorial with great success in environmental conservation. The Zhombe Communal area study came up with the following conclusions:

- Most of the communal farmers are using the indigenous farming methods for sustainable resource management.
- The mostly used indigenous farming methods are intercropping, mixed farming and vegetation strips.
- Indigenous farming methods were found to be 70-80% effective in sustainable resource management.
- Indigenous farming methods ensure that the communal farmers have a harvest each year.

- Scientific and indigenous methods can be used concurrently for better resource management.

Recommendations

The study recommends the following measures to be done as to sustainably manage the resources in the Zhombe communal area:

- All communal farmers to be encouraged to use the indigenous farming methods since they are effective and affordable to them.
- Governmental organizations such as Agritex and EMA to spearhead awareness campaigns on the use of indigenous farming methods since they are always in contact with communal farmers.
- The traditional leadership settings to be involved in the awareness campaign since they have the traditional communication structures in their communities.
- Farmers to be educated on the use of scientific sustainable resource management techniques so as to come up with a broader resource management system.

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3. http://www.cwis.org/wwwvl/indig-vl.html Comprehensive list of indigenous and Fourth World resources on the internet

Monitoring and evaluating the impacts of subtle deforestation on tree diversity in savanna woodlands

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ABSTRACT

Forests and woodlands are critical in the global carbon cycle and in regulating the global climate system. The advent of remote sensing has enabled rapid assessment of deforestation across large spatial scales thus complementing field-based methods that are often time consuming. However, the detection of subtle deforestation has remained a challenge using coarse and moderate spatial resolution satellite data. In this study, we test whether and to what extent the Normalised Vegetation Index (NDVI); Coefficient of variation of NDVI (CNDVI) derived from Landsat and Multi-spectral High resolution WorldView 2 satellite remotely sensed data can be used to detect evidence of logging based on a study area in the savanna landscape of Zimbabwe. Based on the results derived from Landsat and Multi-spectral High resolution WorldView 2, we could detect evidence of logging using remotely vegetation indices. In addition, our results indicate a significant ($P < 0.05$) difference in tree species diversity between logged and unlogged areas.

Key Words: monitoring, deforestation, diversity, woodlands, satellite data, tree-species

INTRODUCTION

Globally, deforestation is the second largest source of carbon dioxide (CO_2) to the atmosphere after fossil combustion (Werf. et al. 2009) and is also a threat to biodiversity. The drivers of deforestation include infrastructure development, agricultural uses, mineral exploitation and wood extraction and these drivers vary in space (Rademaekers et al. 2010). Deforestation involves two processes which are clear-cut logging and selective logging also known as subtle deforestation (Pelletier et al. 2010).

Selective logging is one of the main drivers of subtle deforestation where forest cover is degraded without causing significant changes to crown cover that could be detected using remote sensing. The use of remote sensing provides the spatial information needed to quantify and monitor spatial and temporal variation of forest cover in savanna ecosystems. Moreover, the removal of forest

cover through deforestation has contributed to the reduction in tree diversity (Gibbs et al. 2007; Shvidenko 2008; Umemiya et al. 2010). Deforestation through subtle changes of forest cover has direct impact on tree diversity through tree species loss and indirect impact through loss of wildlife habitat. Thus, understanding how subtle changes influences tree diversity is critical for monitoring and managing forest ecosystems since they harbour terrestrial biodiversity. (Houdet et al. 2012; Proenasa et al. 2011; Schneiders et al. 2012).

Remote sensing has enabled the monitoring and quantification of deforestation rates across large spatial scales thus complementing field-based methods (Gao et al. 2011). Satellite remote sensing enables large areas to be monitored, and changes in forest cover can be routinely monitored. Remote sensing techniques used in deforestation studies include methods such as wall-to-wall mapping, visual photo interpretation, digital analysis and hot-spot analysis. Although the integration of remotely sensed data and Geographical Information System (GIS) has enabled monitoring of land cover changes on local, regional and global scales (Abd El-Kawy et al. 2011; Bakr et al. 2010; Boyd et al. 2002; Kumar 2011), understanding the impacts of subtle deforestation on tree diversity has remained a challenge. Satellite data provide records of landuse patterns of a particular area at any given time. Sensors with coarse and moderate spatial resolution may fail to detect subtle changes such as selective logging activities and partial harvesting (Cabral et al. 2010; DeFries et al. 2007; Ramanikutty 2007; Wyman and Stein 2010a). Therefore the use of high spatial resolution imagery may yield better results on how subtle deforestation influences tree diversity.

Vegetation indices are used in remote sensing to monitor the variations of phenomena in space. Research has shown that vegetation indices are used as a source of information related to the biophysical characteristics of vegetation (Joshi and Chandra 2011; Lyon et al. 1998; Malinveni and Fangi 2010; Viña 2011). Vegetation indices combine the spectral bands to enhance the characteristics of vegetation and they include the Normalized Difference Vegetation Index (NDVI), Simple Ratio (SR), Soil Adjusted Vegetation Indices (SAVI, SAVI1, SAVI2), Weighted Difference Vegetation Index (WDVI), Global Environment Monitoring Index (GEMI).

In this study, we explored the capability and potential of the Multi-spectral High resolution Worldview 2 satellite imagery, as well as Landsat TM for estimating species diversity in an agricultural savanna landscape of Zimbabwe.

Objectives

The main objective of this study test whether Worldview 2 or alternatively Landsat TM can be used to detect evidence of logging based on vegetation indices. The specific objective of this study is to test the significant difference in species diversity between logged and unlogged using WorldView 2 and Landsat.

METHODOLOGY

Study site

The study area is a 100 km^2 area in the woodlands within agricultural areas near Kutsaga Research Station and Harare International Airport (Figure 1). It is located about 16 km to the south east of Harare city. The area geographically lies between latitudes 17° 55' S and longitude 31° 08' E. Mean monthly temperature ranges from 21.4°C in June to 28.2°C in October and monthly respectively. The mean annual rainfall is 850mm and altitude ranges from 1000 m to 1500 m above sea level. The woodland is made up of Miombo woodlands, and tree species are dominated by Mnondo (*Julbernardiaglobiflora*), and Msasa (*Brachystegia spiciformis*). The dominant soils are lixisols, soil with clay-enriched lower horizon, low cation exchange capacity, and high saturation of bases.

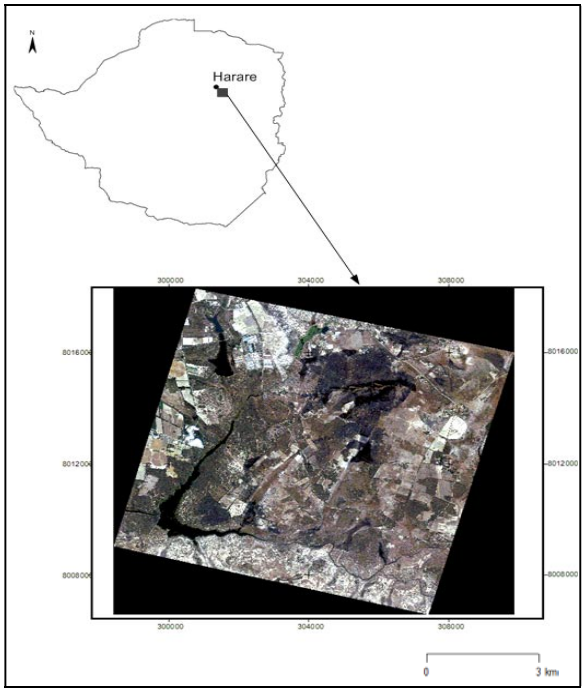

Figure 2: The location of the study area in Natural colour composite. Coordinates shown are based on the Universal Transverse Mercator (UTM) projection, Zone 36, WGS 84 ellipsoid

Remote-sensing data

In this study, the Multi-spectral High Resolution WorldView 2 and Landsat 7 satellite imagery were used. The Multi-spectral High Resolution WordView 2 satellite imagery was acquired on the 24th of July 2012 at an average off nadir view angle of 3.2.°The satellite has a swath width of 16.4km, a revisit time of 1.1 average day and a spatial resolution of 2 m and 0.50 m for multispectral and panchromatic bands respectively. It has an altitude of 770 km that enables frequent revisits at angles closer to the nadia producing higher resolution imagery. Landsat 7 imagery used in this study was downloaded from Glovishttp://glovis.usgs.gov/ and the imagery was acquired on the 11th May 2012. The panchromatic and multispectral bands of Landsat had a spatial resolution of 15 m and 30 m respectively. Due to their differences in the spatial resolutions,

Landsat performs poorly in monitoring of land cover such as tree diversity.A radiometric correction was performed on both imageries. The Multi-spectral High Resolution WorldView 2 imagery was converted to worldview radiance and then to reflectance using Quick Atmospheric Correction (QUAC) (Elsharkawy et al. 2011) Infrared band (NIR) and Red band (Boyd et al. 2002; Wyman and Stein 2010b). The red band (630-690nm) is sensitive to chlorophyll absorption and can be used to differentiate plant types. The Near Infrared (NIR1) (770-895nm) is useful for determining vegetation types, vigour and biomass survey,delineating water bodies, and for soil moisture discrimination. The Normalized Vegetation Index (NDVI) is calculated as;

————(1)

where NIR is the reflectance in the near infrared band and the Red is the reflectance in the Red band. The Normalized Vegetation Index has a range of -1 to +1.

Coefficient of variation of the Normalized Vegetation Index (NDVI) was calculated in GIS as,

$$CV = \frac{\sigma}{\mu} * 100 \qquad \textbf{(2)}$$

Where σ is the standard deviation and μ is the mean of the Normalized Vegetation Index.

Tree species data

We randomly selected six transects in the study site using a GIS software (Figure 2). Transects generated in a GIS environment are random both in the placement of the starting point, minimum and maximum transect length, transect overlap, and the number of transects within a study area. In this study, each transect had a minimum length of 3 km and a maximum length of 6 km. The starting point and the ending point of each transect was navigated using a handheld global positioning system (GPS) receiverat an accuracy between 3 m and 5 m. Along each transect, we defined sample plots of 15 m × 15 m and these plots were 500 m apart. In each sample plot, species names, status of the tree as logged and unlogged was recorded.

Data were collected in early August 2012 and tree species were still in leaf and therefore were easily identifiable. Vernacular names of tree species and specimen of unknown tree species were taken to the herbarium for identification.

Diversity indices

The Shannon diversity index (*H*) and Simpson's diversity index (1-D) (Barry et al. 2013; Magurran 1988) were used in this study as measures of diversity. Shannon's diversity indexis characterized by the number of individuals observed for each species in the ecosystem and it accounts for both species abundance and evenness of the species present. Simpson's diversity index
is a measure of both the richness and proportion of each species. It is the measure of the chance that if two organisms are taken from the environment they belong to the same species**.** We considered using two indicesbecause Simpson's index is particularly sensitive to changes in the relative abundances of the most important species and Shannon's index is particularly sensitive to the number of rare species in a community (Mutowo and Murwira 2012).

The Simpson's (1-D) index of diversity is calculated by:

$$\mathbf{1\text{-}\ D=\sum_{i=1}^{n} Pi^2} \quad (3)$$

where*Pi* is the proportion of the *i*th species in the sampling plot.

The Shannon Weaver index is calculated by:

$$H=\sum_{i=1}^{n} pi \log pi \qquad (4)$$

where*Pi* is the proportion of the *i*th species in the sampling plot.

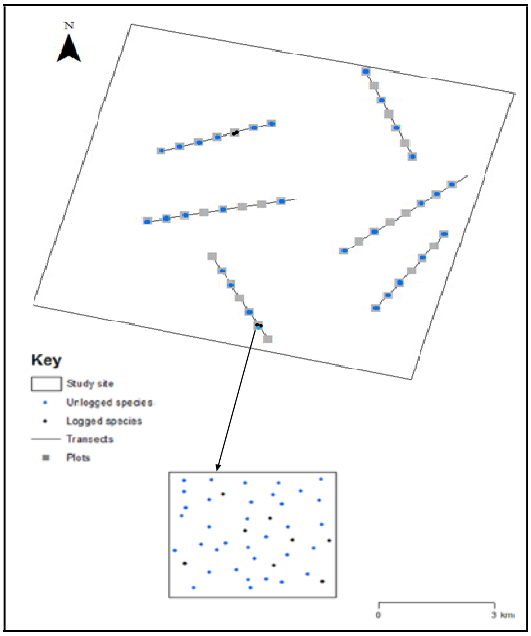

Figure 3: **The distribution of the species data within the study site.**

The species diversity data, Normalized Vegetation Index and Coefficient of Variation of NDVI for both World View 2 and Landsat 7 was tested for normality using Kolmogorov-Sminov (K-S) test and the data significantly deviated from a normal distribution ($P < 0.05$). We tested for significant differences using Mann Whitney in species diversity, NDVI and Coefficient of variation in the Normalized Vegetation Index using Landsat 4TM and the Multi-spectral High Resolution Worldview 2 satellite imagery between logged and unlogged areas at 95%Confidence Interval.

RESULTS

We found a significant ($P < 0.05$) difference between logged and unlogged areas in species diversity. The Shannon's (H) and Simpson's diversity indices yielded significant results for both logged and unlogged areas. The logged areas had low species diversity (Figure 3) compared to unlogged areas for both Shannon's (H) and Simpson's (1-D).

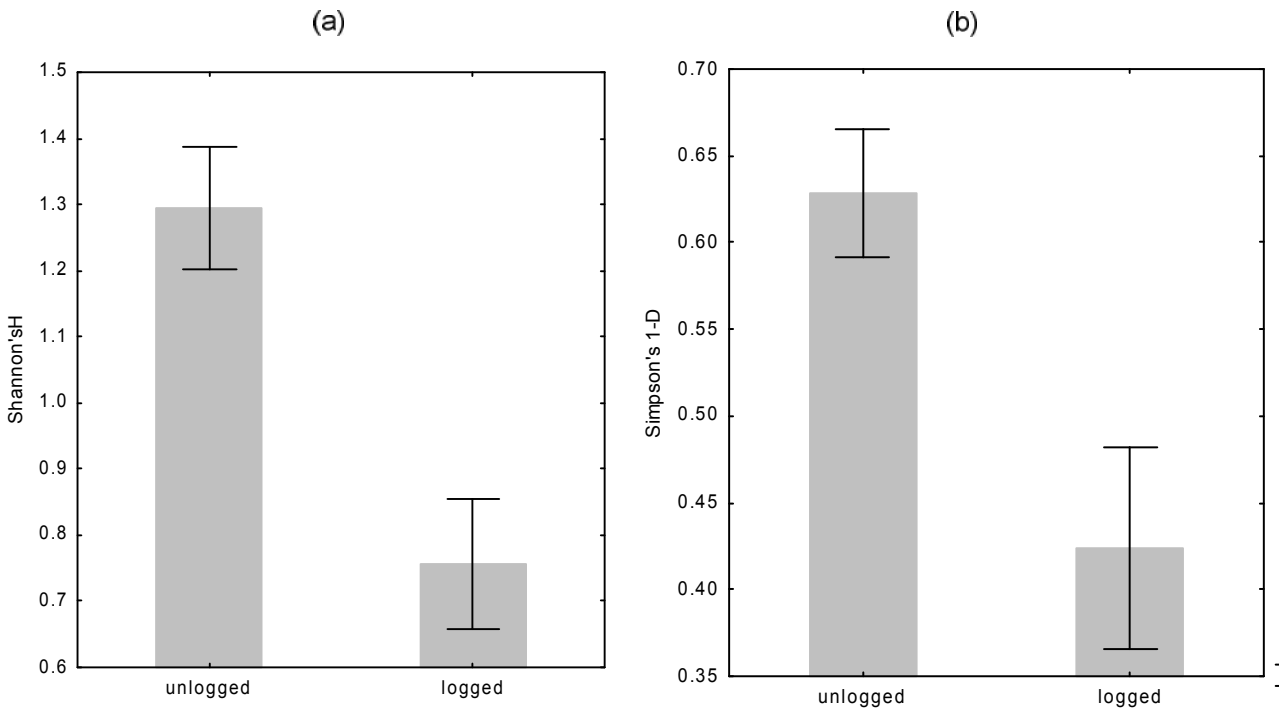

Figure 3: The significant (P < 0.05) difference between unlogged and logged areas using Shannon's H (a) and Simpson's diversity indices (b) (95% Confidence interval).

Figure 4 indicate a significant (P < 0.05) difference in the Normalized Vegetation Index (NDVI) derived from Landsat and WorldView 2 . The Normalized Vegetation Index is significantly higher in the unlogged compared to logged areas for both Landsat and WorldView 2 imageries. However, the difference in the Normalized Vegetation Index (NDVI) is more significant between the unlogged and logged areas using Worldview 2 imagery.

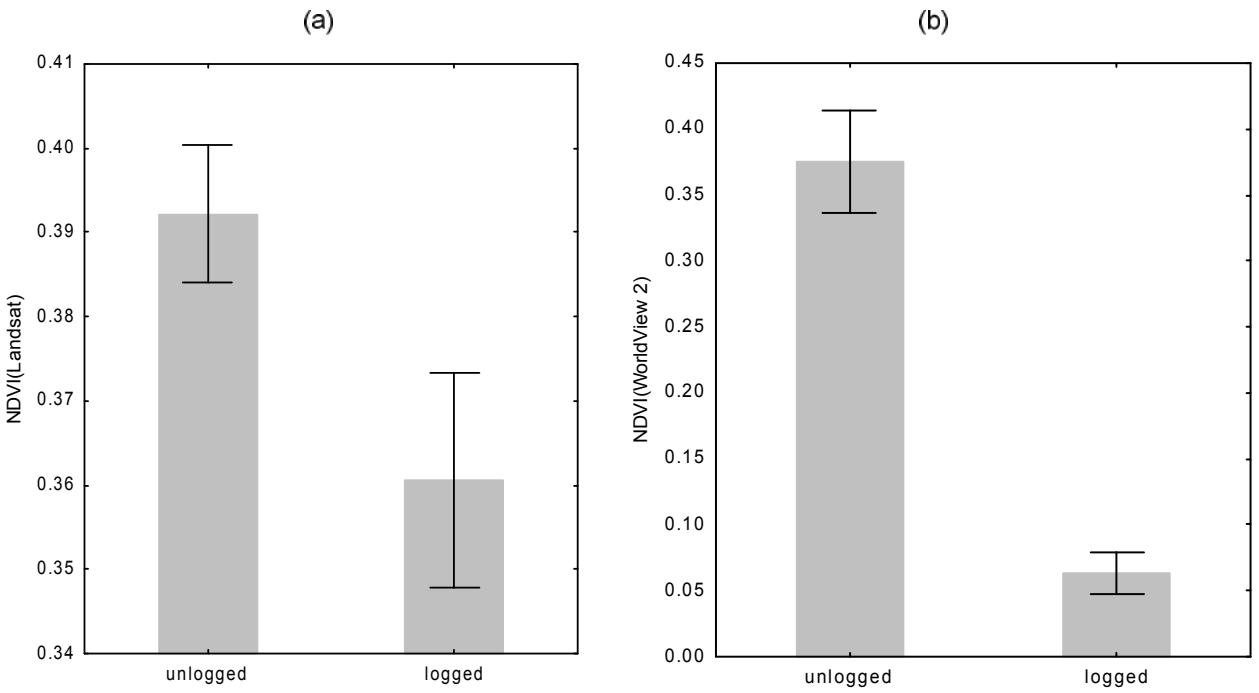

Figure 4: **The significant (P<0.05) difference in the (NDVI) between logged and unlogged areas using Landsat 7 (a) and World View 2 (b) Satellite imagery (95% Confidence interval)**

Figure 5 illustrates a significant (P < 0.05) difference in the Coefficient of Variation in the Normalized Vegetation Index (CNDVI) for Landsat and WorldView 2 between logged and unlogged areas. The Coefficient of Variation in the Normalized Vegetation Index is significantly higher in the unlogged compared to logged areas for both Landsat and WorldView 2 imageries .However, on the Landsat imagery, the coefficient of variation between the logged and the unlogged areas is less significant compared to WorldView 2 imagery.

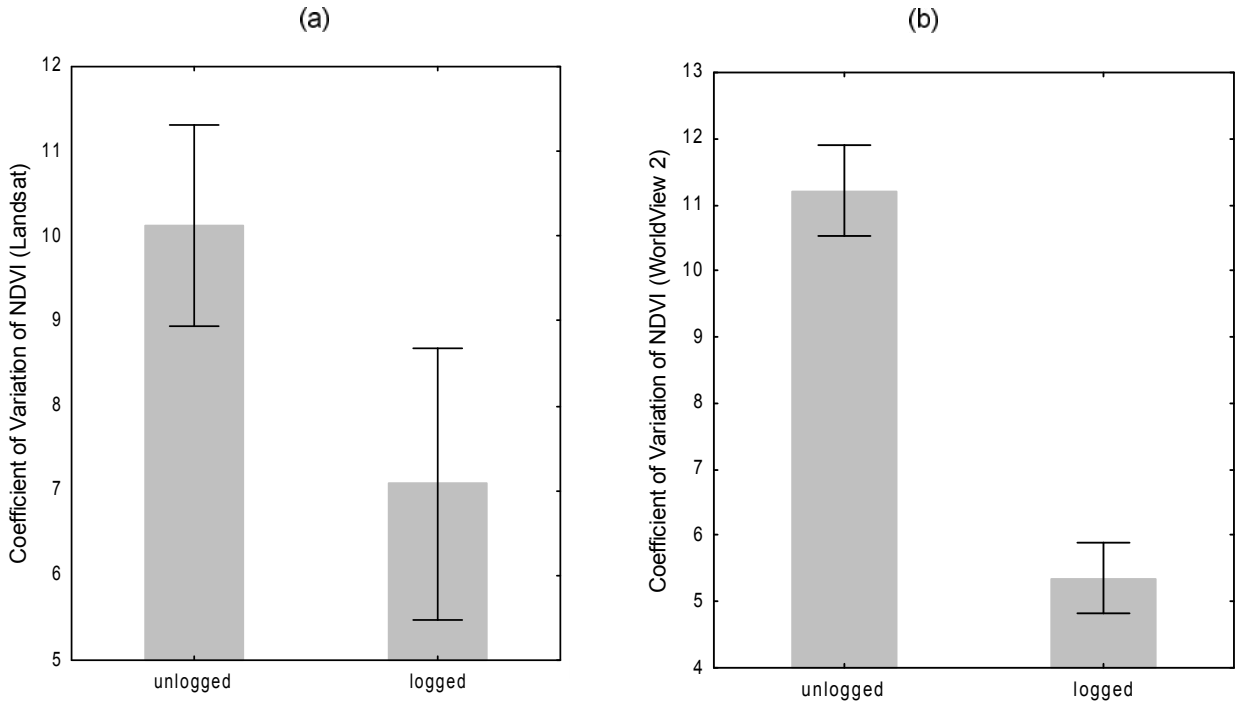

Figure 5:The significant difference (P<0.05) in the Coefficient of Variation in the (NDVI) between logged and unlogged areas using Landsat7 (a) and World View 2 (b) satellite imageries (95% Confidence interva

DISCUSSION

Results of this study indicate that remotely sensed data can be used to detect evidence of subtle deforestation, For example, results indicate a significant (P < 0.05) difference in the Normalised Vegetation Index on logged and unlogged areas for both WorldView 2 and Landsat. In fact, logged areas have significantly lower mean NDVI than unlogged areas. This is not surprising since logging removes green biomass. In addition, these results are consistent with the findings of Pope (2012) who also found evidence of lower NDVI on logged areas compared with unlogged areas.

This study also provides evidence for the effect of logging on tree species diversity. Our results based on ground data indicate that species diversity is higher on unlogged compared to logged areas using Shannon diversity index (*H*) and Simpson's diversity index (1-D). From these results, we deduce that logging has a negative impact on tree species diversity (Hosseini et al. 2012; Mansour et al. 2012).

Similarly, we found the Coefficient of variation which is related with tree species diversity to be significantly (P< 0.05) different between logged and unlogged areas. These results are consistent with the findings of Mutowo and Murwira, who established a significant (P< 0.05) relationship

between the Simpson's index ($1 - D$) and the Coefficient of variation in the NDVI. We therefore claim that remotely sensed data can be successfully used to detect variation in tree species diversity because of subtle deforestation.

Results from data based on Landsat and World View 2 were consistent. In fact, we could detect evidence of logging as well as evidence of the effect of logging using both Landsat and World View 2. Although, the gradient in both NDVI and CNDVI is steeper for WorldView 2 data, however both sensors gave us consistent results. From this evidence, we can deduce that within the landscape considered in this study, both WorldView 2 and Landsat can be useful in detecting evidence of subtle deforestation, as well as its effects on tree species diversity.

Where our study differs from previous studies (Abd El-Kawy et al. 2011; Bakr et al. 2010; Boyd et al. 2002; Kumar 2011) is our focus on detecting subtle deforestation. Previous studies have mainly focused on deforestation by clear felling. However, we caution that our findings are based on a single study area and that the results may not be generalised to other ecosystems. In this regard, it is critical that different study sites be selected to test this hypothesis.

CONCLUSON

In this study, we compared the potential of high-resolution imagery Multi-spectral High Resolution WorldView 2 and moderate resolution Landsat in detecting subtle deforestation within the study region. Our results indicated a significant difference between logged and unlogged areas for both World View 2 and Landsat. We therefore conclude that we can detect subtle deforestation using both World View 2 and Landsat. Moreover, logging has an impact on species diversity as indicated by Shannon (*H*) and Simpson (1-D) diversity indices.

RECOMMENDATIONS

More study sites from other ecosystems need to used to test whether we can detect subtle deforestation using Worldview 2 or alternatively Landsat TM. Moreover, we recommend including all the 8 bands offered by WorldView 2 (coastal blue, blue, yellow, red, red edge, green and near-infrared 1, near-infrared 2) in the analysis though they are expensive to purchase. The coastal blue ranges between (400-450nm), red-edge (705-745 nm), yellow (585-625 nm) and near infrared 2 (860-1040 nm). This will improve accuracy on our results.

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Fuzzy logic control for the maintenance of chains in the bottle washer in the Krones machinery of Germany

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ABSTRACT

The purpose of this research was to come up with an intelligent monitoring tool to reduce the number of breakdowns in Krones machinery. The case of a local beverage manufacturer (anonymous) was used who has installed a bottle washer of this nature. The research was entirely centred on Krones machinery in order to model around similar operational conditions regarding their design orientation and function embedded within them. The bottle washer is complex so much that it is not easy to carry out a successful troubleshooting. For instance, the chains were affected by carbon dioxide. The researchers carried out a company audit, conducted interviews and sent out questionnaires in order to gather relevant data. Different data analysis techniques were used such as the use of the Ishikawa diagram. The results of which were used in intelligent condition-based-maintenance modelling to solve the problem using a fuzzy logic system. MATLAB software was used as a means for data modelling and manipulation.

Keywords: Condition Based Maintenance, Fuzzy Logic, Intelligent Monitoring, Krones Machinery

INTRODUCTION

The Krones Group, headquartered in Neutraubling of Germany plans, develops, and manufactures machines and complete lines branded as the Krones in the fields of process technology, bottling, canning, packaging and intra-logistics. Every day, millions of bottles, cans and specially-shaped containers are “processed” on lines of Krones machines; particularly in breweries, the soft-drinks sector and at still-wine, sparkling-wine and spirits producers, but also in the food and luxury goods sectors, as well as the chemical, pharmaceutical and cosmetic industries. Since being founded in 1951, the Krones Group has evolved far beyond its original role as a mere producer of machinery and bottling lines. The company has meanwhile become an “all-round partner” for its customers, creating harmonious, optimized synergies of mechanical engineering, line-related expertise, process

technology, micro-biology and information technology. Today, Krones is synonymous with "systems engineering" [1].

Maintenance of equipment is a very vital activity among other process segments. Downtime is one of the most costly conditions a manufacturer can reluctantly experience. A proactive technical support program which can generate significant cost savings can be developed. Continuous-monitoring services can also generate cost savings by protecting existing investments.

The case study (anonymous) that the researchers used refers to a Company that installed the Krones machinery. A cleaning machine is used to ensure that any bottles being filled are free from contaminants. Bottles are washed both inside and outside and then dried by the bottle washer as shown in Fig 1 below. The parameters in this machine can be accomplished in monitoring by using an Artificial Intelligent system. Carbon dioxide that comes from the water might cause some problems to the bottle washer, so control and monitoring devices like the POKA-YOKE system can be used to control the gases before entering the machine. This is a proactive type of maintenance to prevent breakdowns and unnecessary shut downs doing crisis maintenance.

Figure 1: Krones group of companies' bottle washer [1]

Carbon dioxide (chemical formula CO_2) is a naturally occurring chemical compound composed of two oxygen atoms covalently bonded to a single carbon atom. It is a gas at standard temperature and pressure and exists in Earth's atmosphere in this state, as a trace gas at a concentration of 0.039% by volume.

CO_2 can cause corrosion in chains and other items in the washer if allowed to dissolve in boiled water. Corrosion will reduce metal thickness in the materials inside the washer. The carbon dioxide does so simply by dissolving in the water and forming a weak carbonic acid which attacks the metal in feed systems, boiler or condensate system.

$CO_2 + H_2O \rightleftharpoons H_2CO_3$(carbonic acid)

Carbonic acid corrodes the chains and other metals inside the washer.

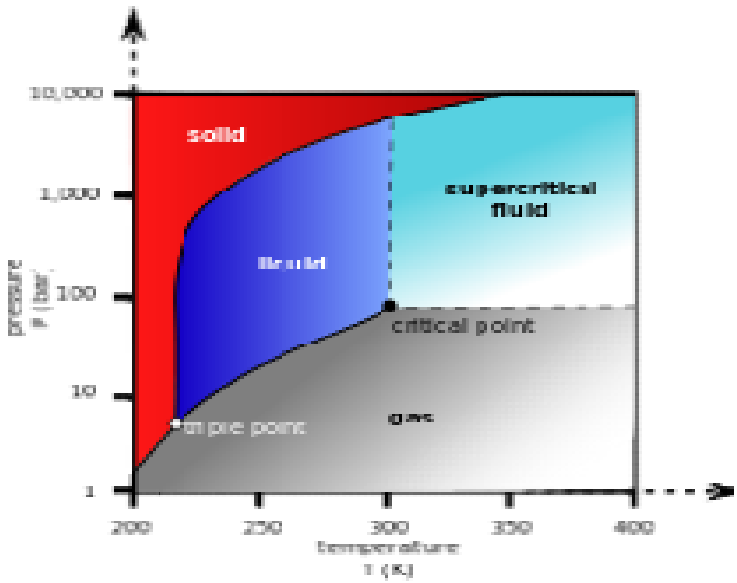

Figure 2: Carbon dioxide pressure-temperature phase diagram showing the triple point and critical point of carbon dioxide [2]

- Percentage of carbon dioxide in the water must not be more than 7%, otherwise corrosion will inevitably occur.
- Power of hydrogen (pH >10.4) shows more carbon dioxide in water [2].

Oxygen is the element with atomic number 8 and represented by the symbol O. Its name derives from the greek roots □ξύσ (oxys) ("acid", literally "sharp", referring to the sour taste of acids) and -γενής (-genēs) ("producer", literally "begetter"), because at the time of naming, it was mistakenly thought that all acids required oxygen in their composition at standard temperature and pressure, two atoms of the element bind to form di-oxygen, a very pale blue, odourless, tasteless diatomic gas with the formula O_2. Diatomic oxygen gas constitutes 20.8% of the volume of air [3].

Oxygen is present in all water, so that red iron oxide forms on a mild steel surface immersed in water. This rusting or, as we call it, corrosion, triunes until the metal is corroded away. If the

amount of oxygen in the water is restricted, the oxide film does not form so readily; but instead, the surface of the steel tarnishes. This tarnish is usually the development of a thin film of iron oxide on the metal surface which is not so fully oxidized as the red iron oxide, and is more dense, thus tending to resist further corrosive attack. In water of increasing alkalinity, the oxide film becomes more stable and gives more protection to the steel, but until a definite alkalinity is reached, it still tends to break down in selective areas, where pits will develop [4].

- percentage of oxygen 0 – 70% is acceptable in the water to the washer
- 70 – 89% oxygen it needs close monitoring, about to be bad
- above 89% oxygen the water must be blocked not to enter the wash
- Appreciation of considering Human Machine Interface (HMI)
- Automatic monitoring of the plant while in the office.

METHODOLOGY

Measuring knowledge management is a critical basis for developing incentives for further stimulating knowledge sharing and networking on local and global levels. Without the ability to quantify, measurement endeavours remains elusive. Further, it is critical to ensure that existing knowledge assets are constantly challenged in a purposeful way. Especially in the current Internet Age, where today's core competencies quickly turn into tomorrow's core rigidities, it is incumbent upon companies to ensure that the knowledge they nurture inside is still relevant to the market thus, the need to explicitly address the issue of developing metrics and incentives for knowledge management.

The following tools were then used to carry out the research by the researchers.

- Company visits (anonymous company in Harare, Zimbabwe which bought Krones bottle washer from Germany)
- Ishikawa diagram (Root cause analysis) using EDRAW MAX SOFTWARE (Finding the reason why a certain problem persists)
- MATLAB software (Input data, model and simulate fuzzy logic systems)

RESULTS

A. Human Machine Interface

The user interface, in the industrial design field of human–machine interaction, is the space where interaction between humans and machines occurs as shown the framework of Fig. 3. The goal of interaction between a human and a machine at the user interface is effective operation and control

of the machine, and feedback from the machine which aids the operator in making operational decisions[5].

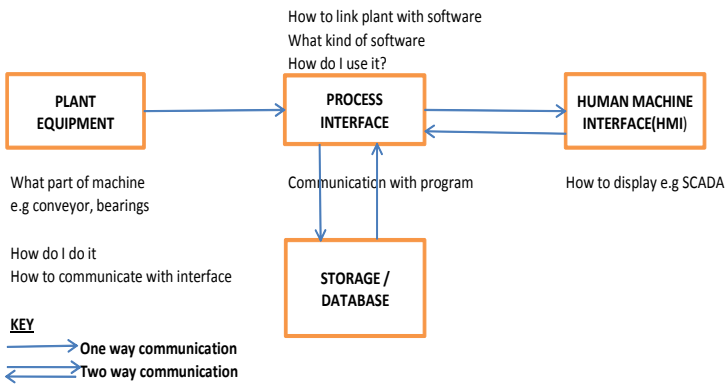

Figure 3: Human machine interface

B. Root Cause Analysis for the Bottle Washer

The pneumatic valve often sticks at start-up. Slack chain will cause uneven entry of teeth through the gears and overload occurs. This is shown in Fig 4 with identified problems using the Ishikawa diagram.

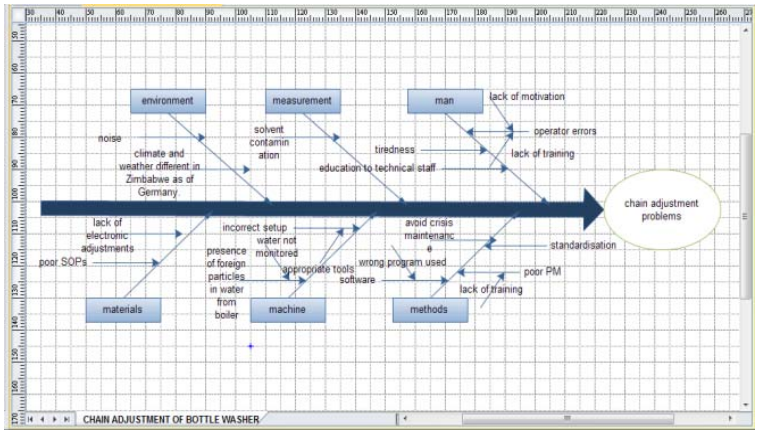

Figure 4: Ishikawa diagram for the chain adjustment

5 FUZZY LOGIC TO THE CHAIN ADJUSTMENTS

5.1: FUZZY INFERENCE SYSTEM (FIS) EDITOR

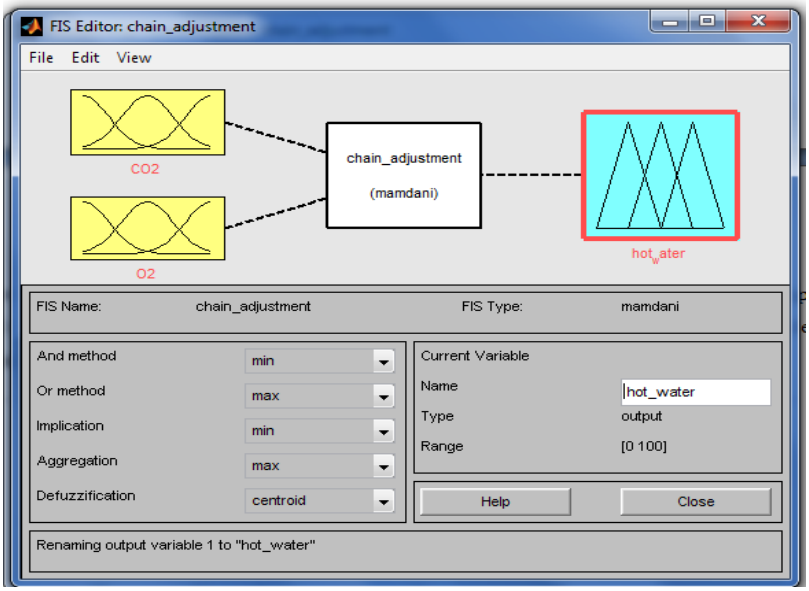

Figure 5: FIS editor for the chain adjustment

MEMBERSHIP FUNCTIONS

If carbon dioxide exceeds 6%, block the water not to enter the bottle washer as shown in Figure 6.

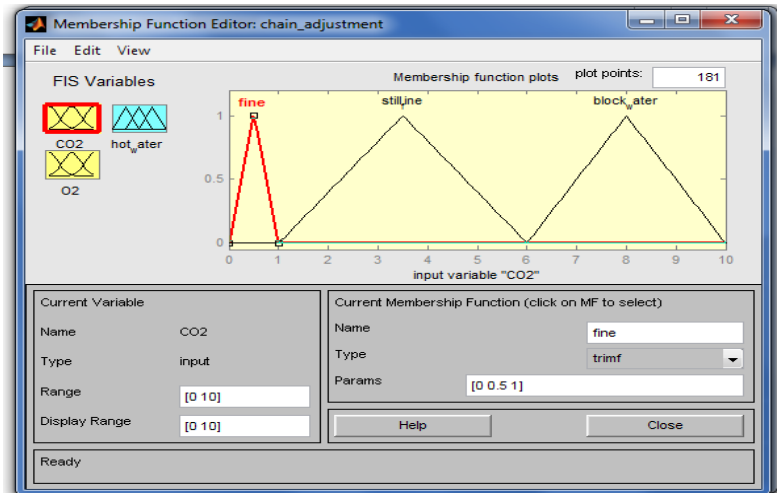

Figure 6: Controlling carbon dioxide entry into the washer

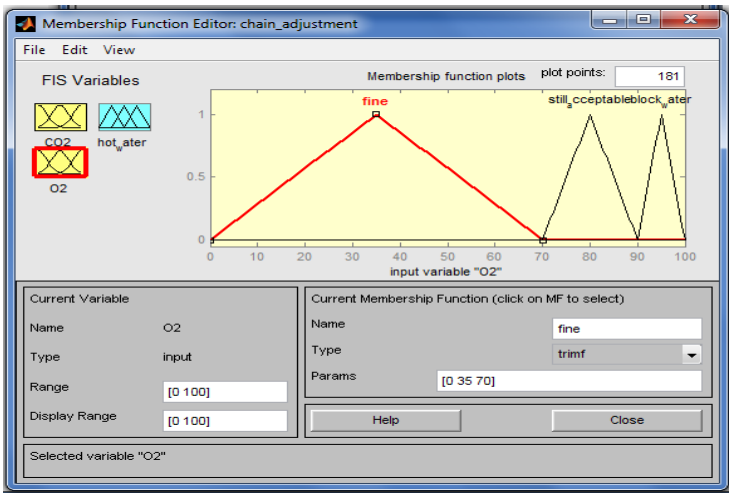

Figure 7: Controlling oxygen entering the washer

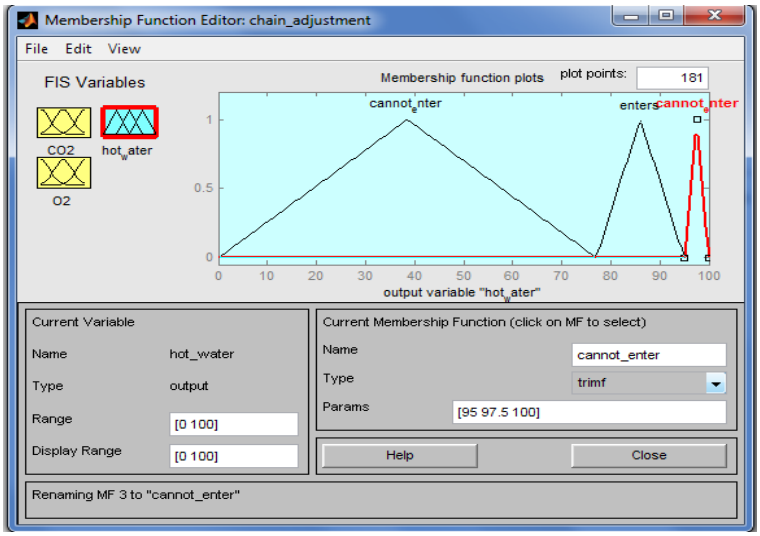

Figure 8: Output of water after the control

Fig. 8 shows the control of water. As from the data, water enters the boiler in the range of 77 – 95°C temperature. Fuzzy logic will be able to control and block the impurities, ie carbon dioxide and oxygen if in excess. Water will only enter at the allowed temperatures and this is going to be monitored by sensors.

RULE EDITOR

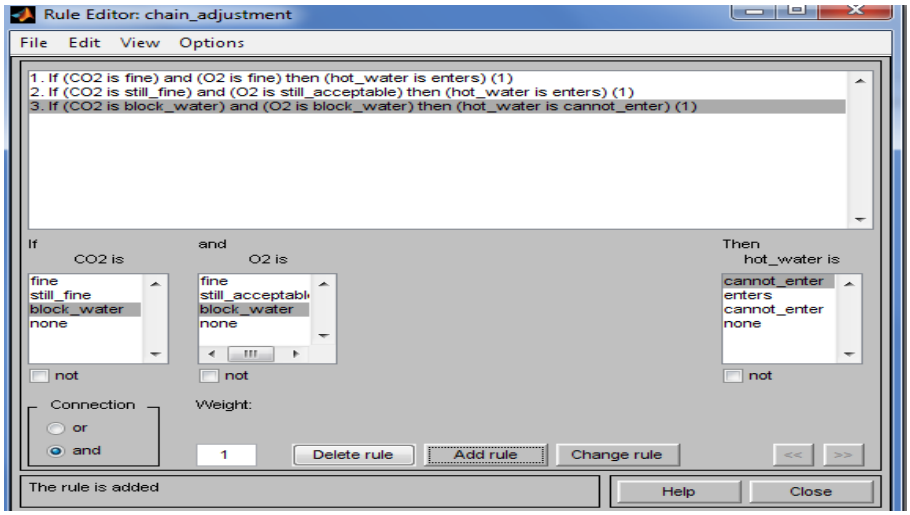

Figure 9: Rule editor for the chain adjustment

Figure 9 has three rules governing the flow of hot water into the washer. These are called the IF – THEN rules.

- If carbon dioxide is fine (acceptable percentage in water) and oxygen is fine (also acceptable range of per cent), then hot water will be allowed to enter since it will not cause corrosion.
- If carbon dioxide is still fine and oxygen is still acceptable then hot water will enter the washer and has allowed temperatures that cannot harm the washer.
- If carbon dioxide is blocked (cannot enter) and oxygen blocked also then hot water cannot enter in the washer.

RULE VIEWER

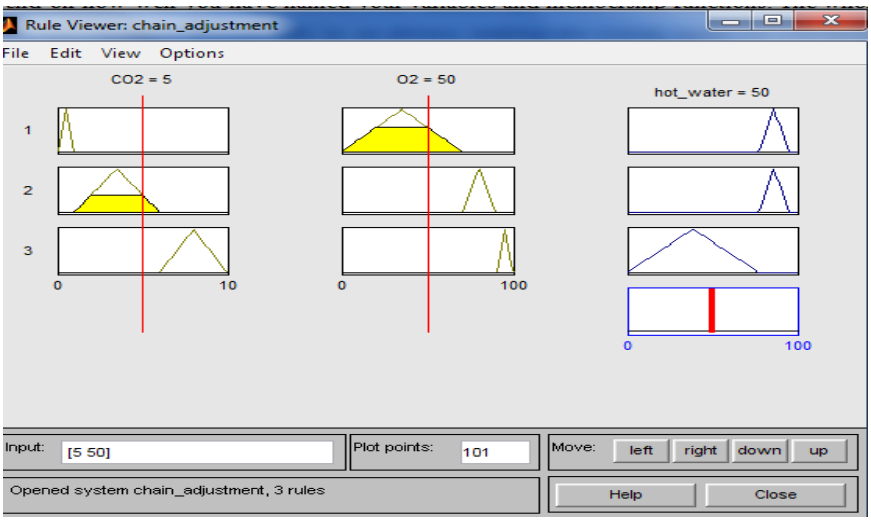

Figure 10: Rule viewer for the chain adjustment

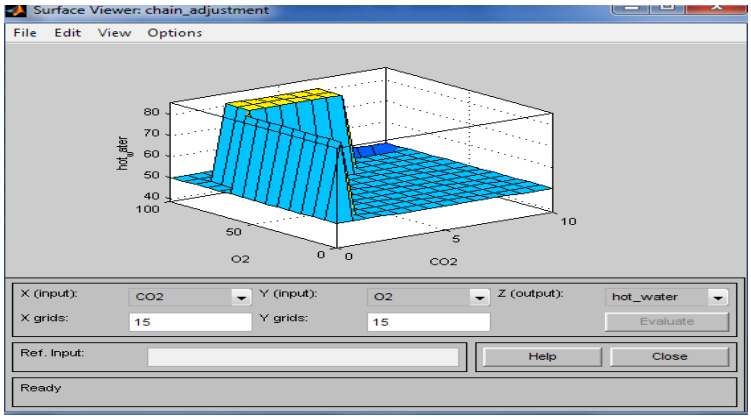

Figure 11: Surface viewer for the chain adjustment

CARBON DIOXIDE AND OXYGEN CONTROL OF THE CHAINS

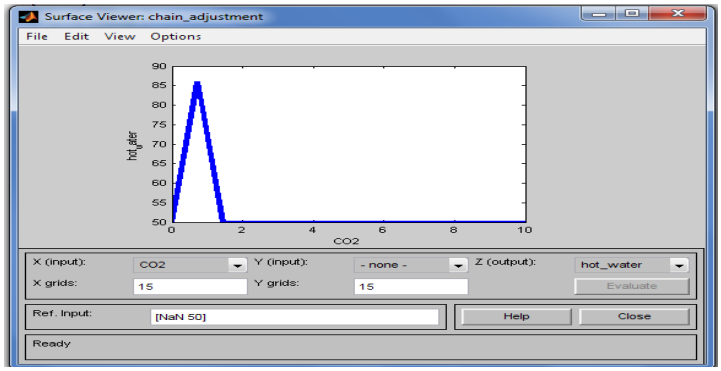

Figure 12: Surface viewer hot water vs carbon dioxide

Hot water is directly proportional to carbon dioxide up to 85% from 50% at 0 - 1% carbon dioxide. It then decreases proportionally again in the reverse direction. Carbon dioxide then increases from 1.75% to 10% and hot water remains constant at 50%. At the beginning it shows carbon dioxide NaN and 50% hot water.

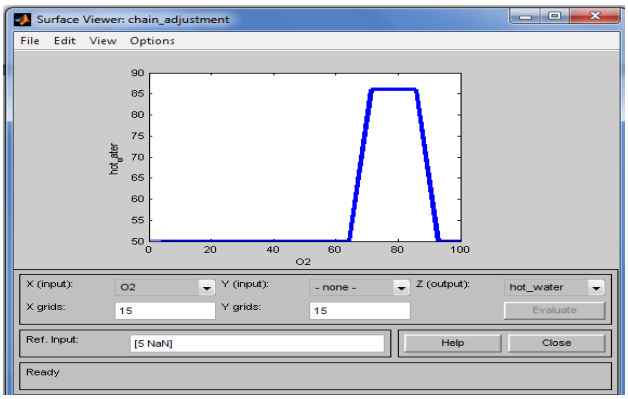

Figure 13: Surface viewer hot water vs oxygen

Hot water remains constant at 50% up to 65% oxygen. Hot water increases directly proportional to oxygen at 65% - 70% oxygen while hot water is varying from 50% - 85%. Hot water remains constant at 85% while oxygen is ranging from 65% - 95%, it then maintains the amount of 50%.

CONCLUSION

Carbon dioxide must be maintained at a percentage below 0.5% to avoid corrosion of the chains. Intelligent maintenance will be done in this way. The intelligent systems will have to work hand in glove with the Supervisory Control and Data Acquisition (SCADA) for monitoring the on-goings of the plant while one is in the office.

Science and Technology is advancing rapidly. The area covered by the researchers is just a drop out of an ocean of knowledge. In the present scenario, if we think of life without a computer then it is very difficult for any firm or organisation to survive in the market. Higher product quality, better reliability, better availability of plants, optimisation of cost and choosing right maintenance procedure is the chief concern nowadays. Generally, the production and maintenance task are going simultaneously, nearly 40 to 45% of production cost generally goes to maintenance work. Hence, there is a lot of scope to minimise the maintenance cost.

This Fuzzy Logic monitoring system that was modelled with MATLAB is an intelligent monitoring system framework that uses fuzzy logic for plant maintenance. Line utilisation will be improved and so is plant availability. Objectives and aims of the researcher were thus achieved in order to suggest a better way to avoid frequent breakdowns to the bottle washer.

The researchers recommend the use of this model for all beverage companies. Beverage companies should also be able to use the latest Siemens programmable logic controllers with Simatic SCADA for the intelligent monitoring to be done at advanced level without some interruptions and also to continuously upgrade the software as they use it. Expert and trained engineers must be used for the **installation.**

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Modelling fire risk in Zimbabwe for the 2012 Fire Season

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ABSTRACT

Veld fires are one of the most important sources of land degradation and desertification. Veld fires have a profound impact on vegetation dynamics by initiating succession, selecting plants adapted to the fire regime in fire-dominated ecosystems, and influencing vegetation productivity and thus litter and fuel load. The conditions for fire are determined by climate and the state of the vegetation. The main objective of this research is to find a way of predicting fire risk of a fire season based on the biomass accumulation of the previous rainy season.In this research the previous year's (2011) biomass accumulated was regressed against the fire occurances of that fire season. (2011).The resulting regression model was applied to the next fire season's fuel load. Accuaracy assessment shows that agro ecological regions 2 and 3 were most affected by fires and were predicted to be at high risk.

Key Words: fire risk, veld fires, vegetation, fire season, biomass.

INTRODUCTION

Fire is a common phenomenon in most parts of the world particularly in Africa. As a result, Africa is referred to as the fire continent due to widespread occurrence of biomass burning in the savanna biomes. It is recognised as a natural and important ecological factor of the environment in different vegetation types and is a frequent disturbance that functions as a 'depressant effect' in many savanna systems (Bond et al., 2005). The occurrence of fire is a key ecological process defining the structure and composition of nearly all biomes worldwide e.g., boreal forests, temperate forests, tropical forests, tropical and subtropical savannas, woodlands and open forests (Bond et al, 2004 and Bergeron et al 2004). Forest fires are vital in initiating natural processes of vegetation succession (Sunar and Ozkan, 2001). Fires also play a pivotal role in landscape management, disease control and vegetation succession (Galanter, M et al 2000). It is impossible to stop nature, but it is possible to map veld fire risk zones and thereby minimise the frequency of fire and avert damage (Erten et al 2001 and Jaiswal et al 2001). Veld fire risk zones are locations where a fire is

likely to start, and from where it can easily spread to other areas. Anticipation of factors influencing the occurrence of fire and understanding the dynamic behaviour of fire are critical aspects of fire management.

The occurrence of fire is dependent on the spatial and temporal variation in fuel load. The spatial and temporal variation in fuel load in semi-arid areas such as, Savanna and Mediterranean ecosystems are caused by seasonal or interannual rainfall variability. (Mermoz et al., 2005)

Understanding the spatial and temporal variation in fuel load is critical in modelling fire risk areas. To understand the variation in fuel load, there is need for robust methods which can provide accurate and up-to-date information on the state of the environment in different areas. In this regard, remote sensing and geographic information systems become useful tools. The main objectives of this study is;

- To find a way of predicting fire risk of a fire season based on the biomass accumulation of the previous rainy season.

NDVI is a quantitative measure of vegetative spectral properties that attempts to measure biomass or vegetative vigour.NDVI values range between -1 and +1 ,Values greater than 0.2 refer to green and healthy vegetation and hence high fuel load.Fire is a key ecological process defining the structure and composition of nearly all biomes worldwide; boreal forests, temperate forests, tropical forests, tropical and subtropical savannas, woodlands and open forests (Bond et al, 2004 and Bergeron et al 2004).Forest fires are vital in initiating natural processes of vegetation succession (Sunar and Ozkan, 2001). Fires also play a pivotal role in landscape management, disease control and vegetation succession (Galanter, M et al 2000).

In this paper veld fire risk zones are locations where a fire is likely to start, and from where it can easily spread to other areas (Jaiswal at al 2001). Anticipation of factors influencing the occurrence of fire and understanding the dynamic behaviour of fire are critical aspects of fire management (Dong et al 2006).Changes in fuel load in semi-arid, Savanna and Mediterranean ecosystems caused by seasonal or interannual rainfall variability can limit or promote fire spread (Mermoz et al., 2005)

OBJECTIVES

The Objectives of this research were:

i. To estimate the fuel load available in Zimbabwe for the 2012 fire season using satellite data; and.

ii. To find a way of predicting fire risk of a fire season based on the biomass accumulation of the previous rainy season.

METHODOLOGY

A 500m x 500m spatial resolution Moderate Resolution Spectroradiometer (MODIS) image was used to derive the wet season accumulated biomass, approximated by the Normalised Difference Vegetation Index (NDVI). The NDVI was calculated using the MODIS image near infra red band and visible red band. The image of 15th March 2012 was used because it represents the time of the year before vegetation reaches its senescence and also because the image was cloud free. The NDVI is calculated using the following equation :

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad \text{[Equation 1]}$$

A burnt area map for 2011 was used to randomly generate 200 sample points. The sample points were separated to 100 points where fires occurred and another 100 points where fires did not occur in a Geographical Information System (GIS).

The NDVI values for the 200 sampled points for the 5,8,10 and 15 March 2011, with and without fires were extracted and regressed with fire presence and absence for the 2011 fire season. The results of the regression analysis of the 2011 fires and NDVI were used formulate a regression equation to predict the 2012 fire risk zones using vegetation available in 2012.

RESULTS

There was a significant correlation between NDVI for the 15th of March and fires for the 2011 fire season. A regression equation was formulated using this relationship for the 2011 fire season and was used to predict the 2012 fire risk zones. To predict the 2012 fire risk zones NDVI for the 5th of May 2012 was used as shown below,

FR =exp((4.705*V)-2.927))/((1+exp(4.705*V) -2.927 Equation 2

In this equation, FR is the numerical index of fire risk zone and V is the vegetation condition. For easy visualisation veld fire risk zones were classified into four classes namely low risk, medium risk, high risk and extreme risk.

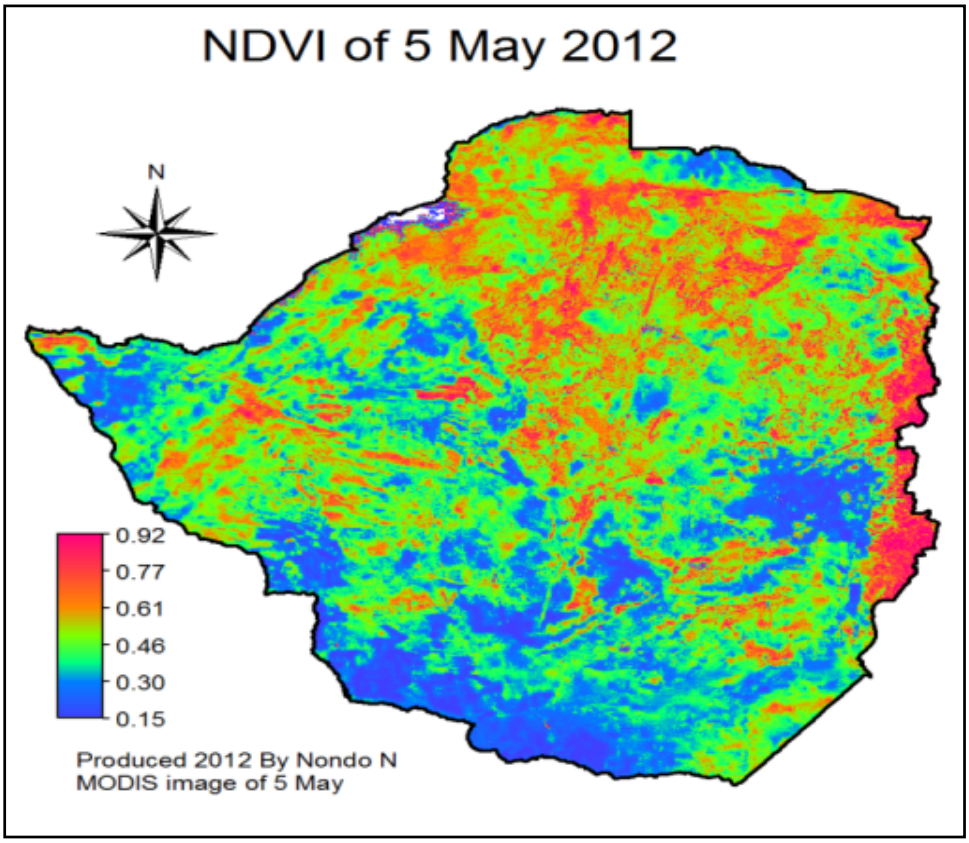

Figure 1 : NDVI for 5 May 2012

The fire risk prediction for 2012 indicate that Mashonaland West, Manicaland and Mashonaland East have areas at high risk to fire in 2012.

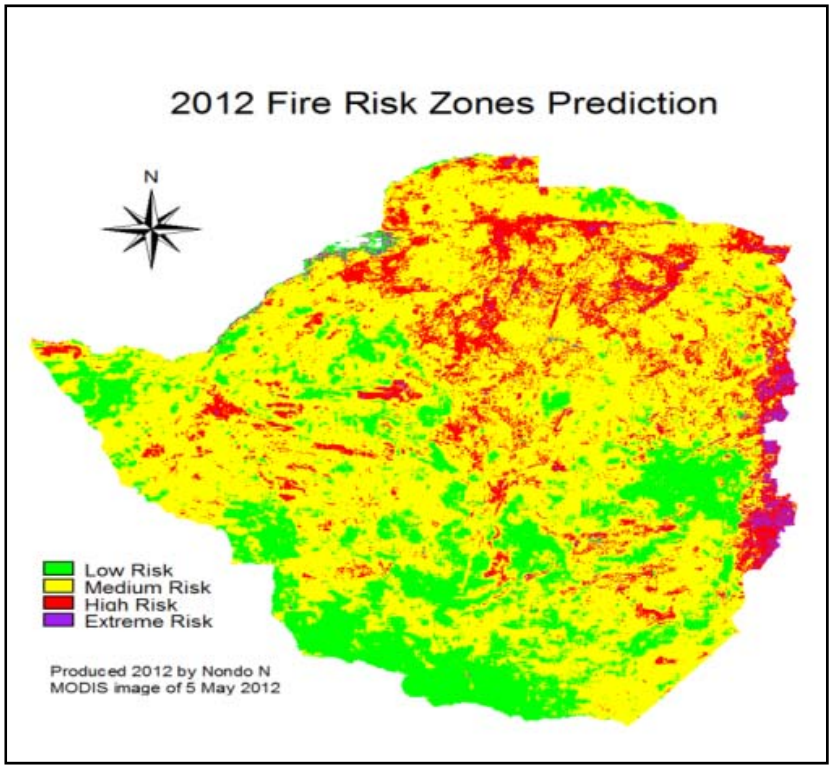

Figure 2: Fire Risk Model for 2012

CONCLUSION

In conclusion fuel fire risk can be modelled using remote sensing technologies and vegetation as evidenced by the high hectarage of land lost to fires in agro ecological regions 2 and 3 which were predicted to be mostly at high risk to fires.The model predicted the agroecological 1 region to be at high risk due to the many plantations in the area which in actual fact did not burn due to the various fire suppresion strategies put the area.

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Remote Sensing and GIS Applications on Change Detection Study in Mafungabusi Forest – Gokwe (Zimbabwe), Using Multi Temporal Satellite Data (1992 – 2008).

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ABSTRACT

Mafungautsi forest has a community based management model. There is a co management between the Forestry Commission (forestry authority) and the surrounding communities under the adaptive management approach. The intention of this study was to ascertain if the intentions of Community Based Natural Resources Management (CBNRM) approaches are being adhered to, the challenges and whether the forest (vegetation cover) has thrived under this management regime. The aim of this study was to determine vegetation cover change before and after CBNRM technique was implemented. Geographical Information System (GIS), Remote Sensing and Global Positioning System (GPS) were the major tools that were used in the change detection study. Vegetation cover change that is the area covered by vegetation within the whole forest was 68.32% in 1992; 69.79% in 1998; and 55.21% in 2008. Decrease in vegetation cover has been noted from 1998 – 2008 which can be attributed to implementation of conflicting policies within Mafungautsi forest.

Keywords: Change Detection, CBNRM, GIS, GPS, RMCs, and Vegetation Cover Change.

INTRODUCTION

Background Information

In Zimbabwe Mafungautsi State Forest Reserve (Figure 1) is located in west central part of the country [1]. Mafungautsi forest 82 100ha in size, 18.5°S and 29°N is located 11 km South of Gokwe Centre in the Midlands Province of Zimbabwe. It lies within the agro – ecological region 3 of Zimbabwe, which is characterized by a mean maximum temperature of 30°C and receives 650 – 800 mm of annual rainfall with a mid – season dry period [2]. Kalahari sands cover the bulk of Mafungautsi forest and surrounding areas. The sands comprise deep unconsolidated tertiary sands

of Aeolian origin (1). The Kalahari sands are uniform physically and chemically. The soils are well drained, deep and have medium-grained sands (2). The sands are extremely infertile (1) and this severely limits the potential for crop production. The natural vegetation in Gokwe is miombo woodland, dominated by *Brachystergia spiciformis* in association with *Julbernardia globiflora* (3). The vegetation shows a distinct catenary pattern with Barkiaea on the ridge, while *Burkea*, *Terminalia*, *Combretum* mixed scrub and occasionally *Colophospermum mopane* are found on steep lines and vleis (4).

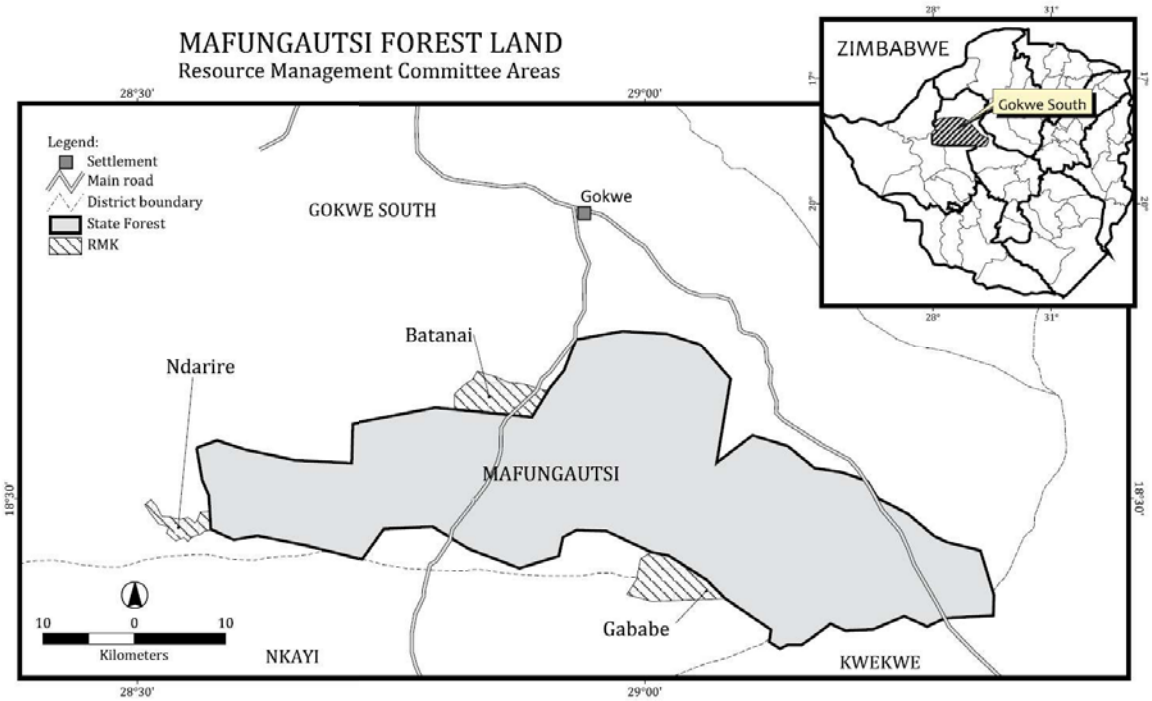


Figure 1: Mafungautsi forest Map (Courtesy of [3])

Mafungautsi is one of the 21 state forests falling under the control of the government's Forestry Commission. Covering some 82,100 hectares of forestland, it comprises almost 10% of the nation's 827,200 hectares of indigenous forest reserves, most of which are in the western parts of the country. Mafungautsi was designated a state forest in 1954. Like most such forests, its statutory designation involved the eviction of peasant communities who resided in that area at the time. Its history has, therefore, been characterized by tenurial and other conflicts between official state forest custodians and the surrounding peasant communities [1]. Although the state may view the state forests as sources of revenue (from the extraction and sale of timber resources), retreats for recreation and repositories for genetic material, local communities perceive these forests as their own customary land and an inalienable basis of their livelihood and cultural and spiritual needs [4].

Increasingly, communities living on the margins of the forests are demanding that their traditional and political rights to the land and its resources be recognised [5]. The Community Based Natural Resources Management (CBNRM) Models were seen as essential in the conservation of forestry resources in Mafungautsi.

The recognition that the conservation of forest reserves in Zimbabwe could only be secured with the support and cooperation of neighboring peasant communities dates back to the 1960s (5). Over the years, a number of management systems have sought to involve local communities in resource management, ranging from "community development" in the 1960s [6], to “co-management” and “resource sharing” in the early 1990s [4] and Adaptive Collaborative Management (ADM) implemented from 2000 in Mafungautsi.

In remote tropical regions, satellite remote sensing (via radar or optical sensors) may be the only feasible method to monitor forest clearing and land cover/land use conversion over large areas (6). This study used remote sensing data to investigate vegetation changes in Mafungabutsi forest that was as a result of the CBNRM models employed within the area from the period 1992 – 2008.

PROBLEM STATEMENT

In Mafungabusi the Resource Sharing Project (RSP) and the adaptive collaborative management were implemented with the prime objective of sustainable natural resources management. There has been evidence of unsustainable methods of resource exploitation an example being lutope vlei where broom grass (*Aristida junciformis*) was uprooted leaving an area of 3 hectares bare. Overgrazing has also been noted resulting in a decrease in the yield of thatch grass (*Hypparrhenia femitina*) collect from the vlei of special concern is the Nyan’ombe vlei in Batanai. Lutope and Nyan’ombe vlei are both in Mafungabutsi Forest. The Forest Protection Unit (FPU) recorded an increase in veld fire incidences from 4 in 1996 to 15 in 2002 mostly as a result of using primitive honey collection methods.

The incidences stated above have lead to more questions being asked about the natural resources management strategies administered in Mafungautsi. Management strategies need to be monitored so as to ascertain the effective and efficiency level thereby ensuring intervention if there is a drift from the intended goals.

SIGNIFICANCE OF THE STUDY

In 1993 the Forestry Commission (FC) initiated the Resource Sharing Project (RSP) in Mafungautsi, with assistance from the Canadian International Development Agency (CIDA). This was a pilot project to test co-management as an alternative to exclusionary state control. (7) concluded from previous reviews conducted in Mafungautsi that the CBNRM techniques were not yielding the intended results since Resource Management Committees (RMCs) had limited tenurial rights. In 1999 the Center for International Forestry Research (CIFOR) initiated its Adaptive Collaborative Management (ACM) Programme with research projects at multiple sites in Cameroon, Ghana, Zimbabwe, Malawi, Indonesia, the Philippines, Nepal, Kyrgyzstan, Madagascar, Brazil and Bolivia (8). Mafungautsi being the only forest in Zimbabwe were both the RSP and ACM has been implemented, this study will be able determine if two management strategies when combined are effective in forest management.

OBJECTIVES

OVERALL OBJECTIVE

- The overall objective of the project is to assess the impacts of Community Based Natural Resources Management (CBNRM) approaches on vegetation cover in Mafungautsi from 1992 - 2008.

SPECIFIC OBJECTIVES

More specific objectives can be defined as:

- To determine vegetation cover change in Mafungautsi.
- To determine the rate of vegetation cover change in Mafungautsi.

RESEARCH QUESTIONS

- Has vegetation cover changed in terms of increase, decrease or no change?
- If change occurred what is spatial and temporal extend?
- What are the causes and implications of change to forest management?

METHODOLOGY

RESEARCH DESIGN FOR REMOTE SENSING AND GIS

Satellite images (Landsat TM) of the same seasonal period per given year were used for the purpose of this study. Images were taken from March to April for year 1992, 1996 and 2008 were used for this study. At this time of the year the trees are still in full leaf and the grass is senescent. This avoids a mis-classification of grass and tree reflectance and enables distinguishing both categories very well. The year 1992 was selected since this was the year of RSP implementation, 1996 was selected since this was after the implementation of the RSP and 2008 was after the implementation of both RSP and the

ACM. The satellite images were obtained from the Forest Commission – Research and Training Division. Landsat TM were used for this study since the thematic mapper (TM) sensor of the LANDSAT satellite records the reflected solar radiation not only in the visible spectrum but also the Near, Middle and Thermal Infrared (7 spectrum band) different vegetation cover types can be distinguished.

A Universal Transverse Mercator grid network provided a framework to localize change estimates in remote forest region with few roads or physical landmarks (8). The geo-referenced satellite image of Mafungautsi was used as the sample frame for this study. Sample plots were selected with respect to; distances from the road and vegetation structure, the two factors were considered so as to reduce the surveying costs whilst at the same time returning relevant vegetation information. 50 sampling points were selected with the furthest from the road being 3km. Vegetation phenomenon were taken note of along the transect to come of a reference vegetation directory that was constituted by location and vegetation variables. The field survey observation map (Figure 2) is shown below.

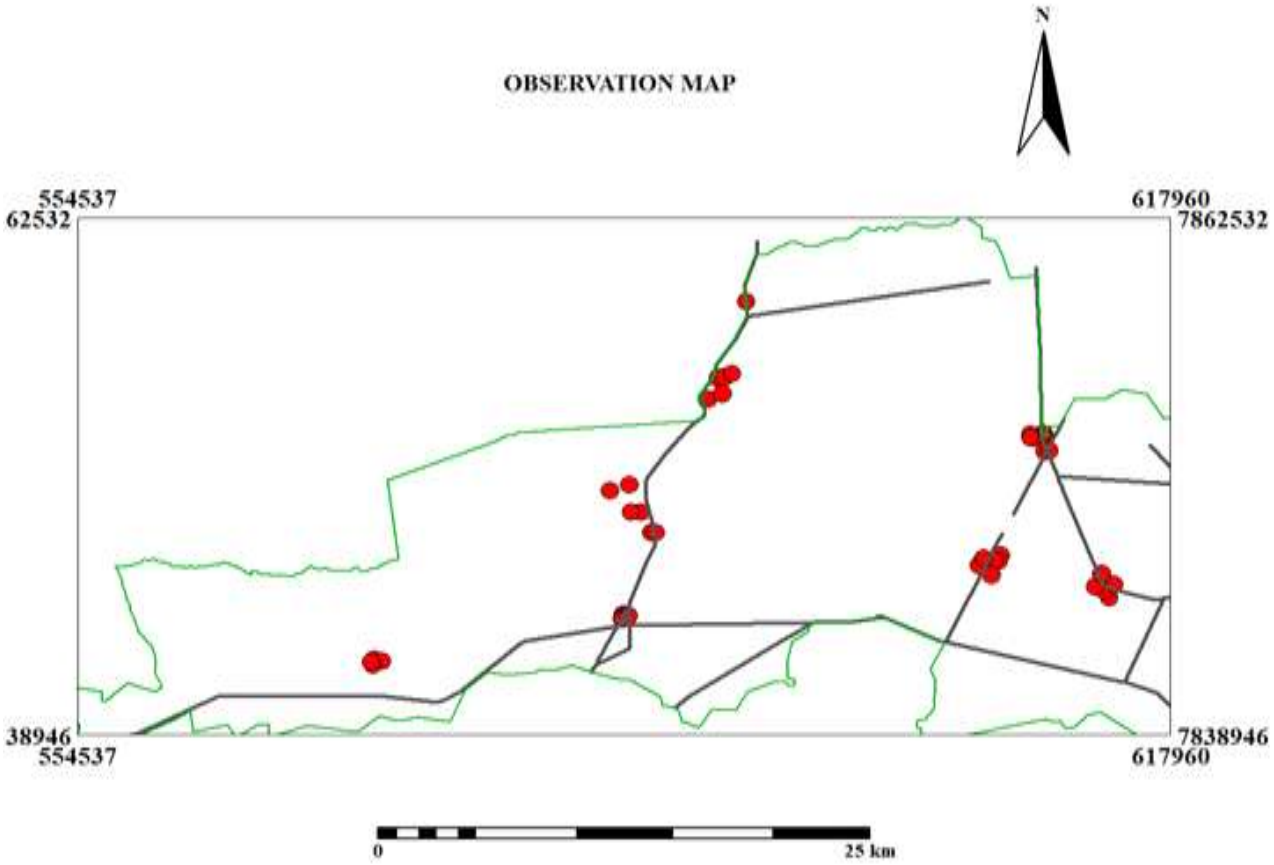


Figure 2: Field Survey Observation Map

The points that were selected points are shown in red in Figure 2 whilst the forest roads are in dim gray.

2.2 IMAGE PROCESSING

Satellite images of year 1992, 1996 and 2008 were georeferenced to make the images spatially correct, resampled and classified (see Figure 3 for a methodology flow chart). Geo-referencing was done mainly by using the tie points (master) against the satellite image (slave). (10) state that a recommended maximum tolerable Root Mean Square Error (RMSE) value of 0.5 pixels whilst (11) identified acceptable RMSE values ranging from 0.2 pixels to 0.1 pixels in change detection studies. This study had an RMSE value of 0.066 – 0.265.

Supervised classification was used in image classification whereby the pixel were assigned the domain classes they represent within the forest area. Vegetation comprised of the domain classes; dense vegetation, sparse vegetation and grassland. The generated reference map was referred to in training of the image. The maximum likelihood classification method was chosen for use in image

classification. (12) used maximum likelihood algorithm in a change detection study in China and argued that it is appropriate and efficient in uneven study area for supervised classification.

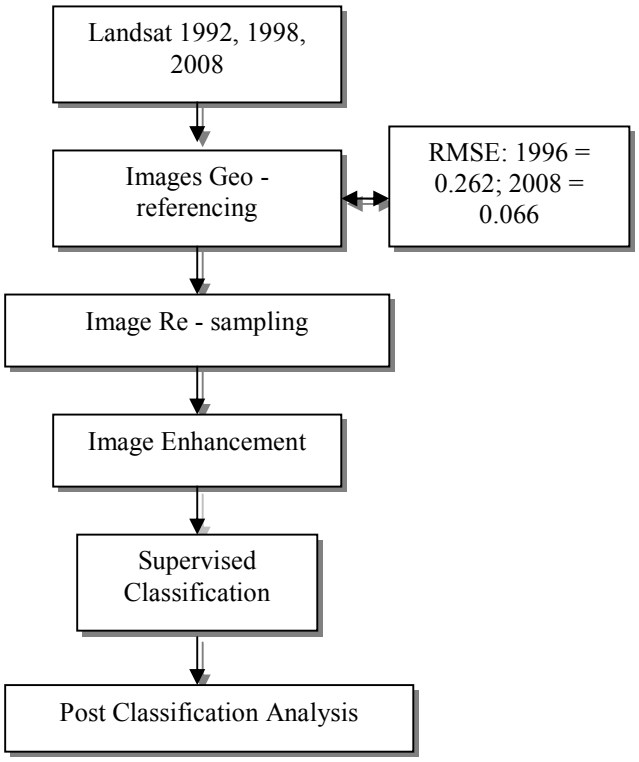


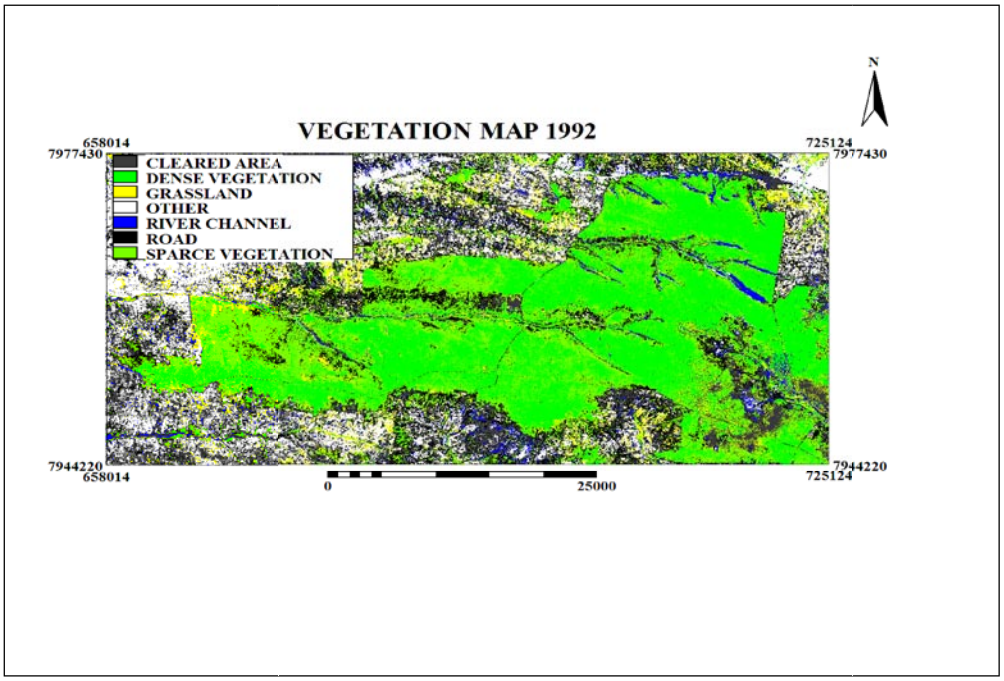
Figure 3: Methodology Flow Chart

The Methodological Flow Chart list the different stages from Data Acquisition and Image Processing

RESULTS

The vegetation map of 1992, 1996 and 2008 are shown below showing the vegetation cover change over the years (Figure 4 – Figure 6).

Figure 4: Vegetation Map 1992.



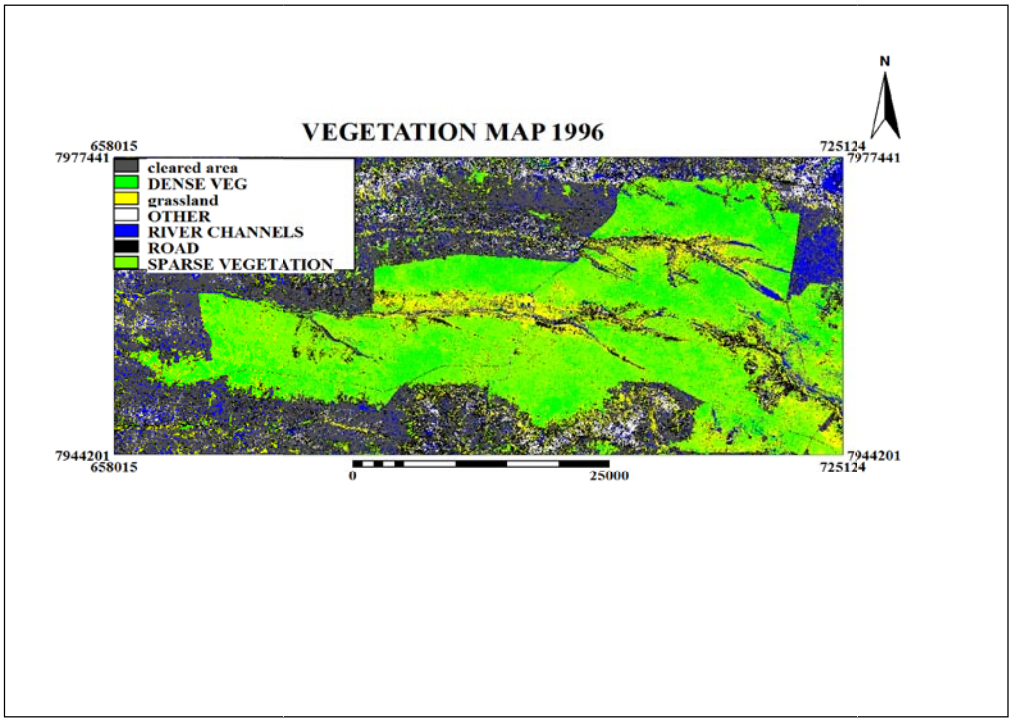


Figure 5: VEGETATION MAP 1996

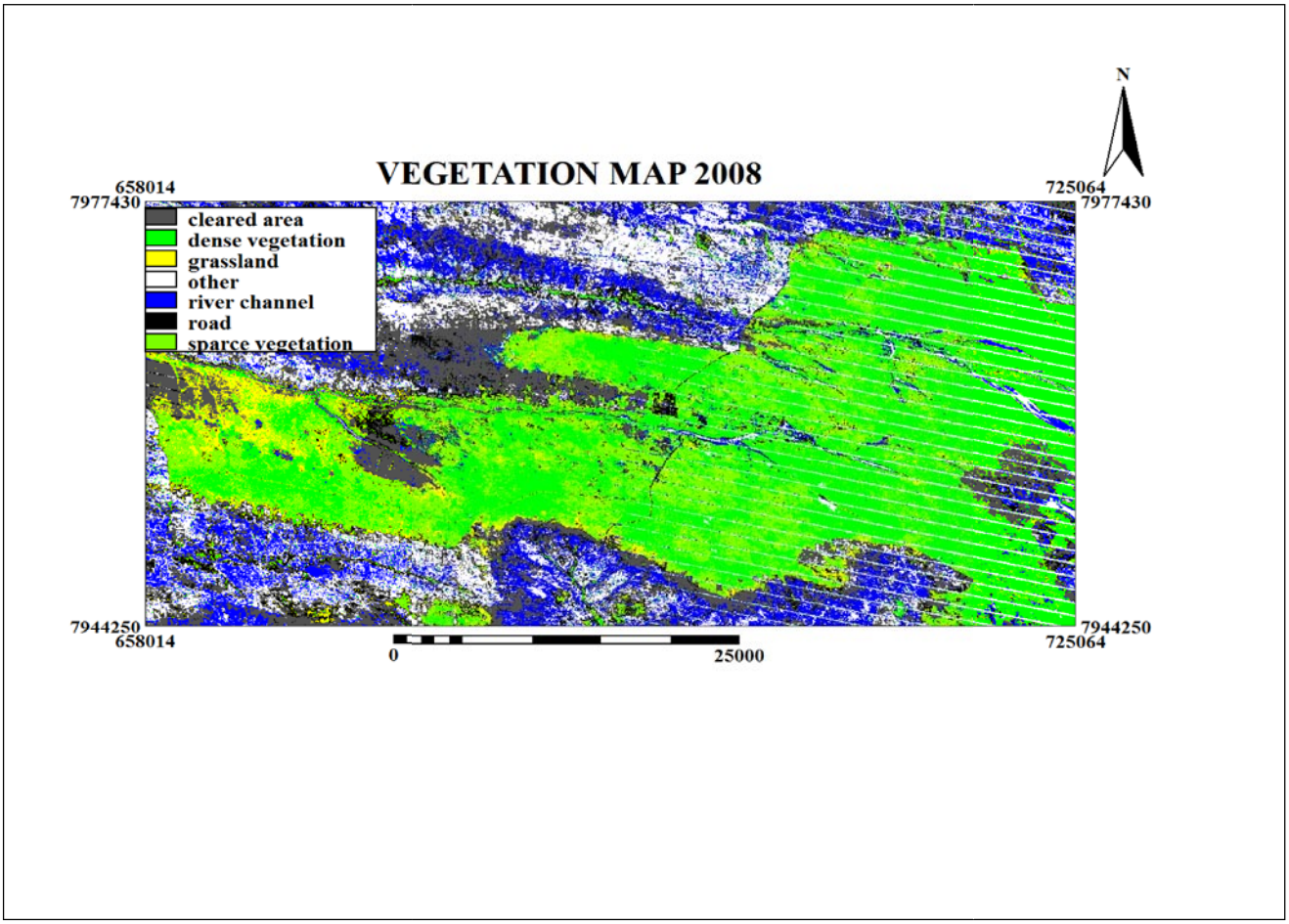


Figure 6: Vegetation Map 2008.

VEGETATION COVER CHANGE

Land cover tables were commutated by the software. Vegetation cover percentages were calculated using 2 variables being total vegetation cover over the total hectarage of the forest.

Table 1: VEGETATION COVER CHANGE

	YEAR		
	1992	1996	2008
VEGETATION COVER	68.32%	69.79%	55.21%
		37911.7ha	37115ha

The total area covered by vegetation in year 1996 was 37911ha whilst in 2008 it was 37115ha. The vegetation cover change of 1996 – 2008 was 796.7ha which translates to a rate of change of 66.4 ha/yr in forest cover.

DISCUSSION

VEGETATION CHANGE DETECTION 1992 - 1996

[7] carried out a change detection study in Mafungautsi Forest from year 1976 – 1996 using aerial photographs and came out with the following figures; the forest declined from 68% in the 1976/7 to 66% in 1984 but rose again to 71% by 1996. The following vegetation changes where noted within Mafungautsi using satellite images in this study (see Table 1); the forest rose in vegetation cover from 68.32% in 1992 to 69.79% in 1996 and then declined to 55.21% in 2008. There was a vegetation cover decline of 796.7 hectares from the period 1996 – 2008 which translates to 66,4 ha/yr, this is an alarming rate of vegetation cover. The vegetation cover of 1976/7 of 68% was almost the same as the vegetation cover of 1992 0f 68.32%. 1976/7 was during the colonial era and declined in 1984 to 66%. (13) termed the conflict between the government and the peasants on natural resources the "weapons of the weak". The methods that have been used include poaching, arson and setting of forest fires. The approach by the peasants has affected the vegetation density and hence the vegetation cover in the then designated forest of Mafungautsi.

[7] in his study on CBNRM in Mafungautsi claims that when the Resource Sharing Project (RSP) was introduced CIDA devoted a large fund for recurrent expenditure; including salaries; allowances; logistical requirements (like vehicles and tractors); related infrastructure developments including the construction of a Resource Sharing Center and accommodation, including houses for members of the FPU. The funding of such a magnitude lead to a reduction in poaching activities since the FPU patrolled the area; institutional capacitating of the government organ the FC that ensured the monitoring of RMCs and other silvicultural cultural activities such as fireguard construction; and the RSP revenue was realized making the communities conserving so as to realize the same socio – economic gains in future.

VEGETATION CHANGE DETECTION 1996 – 2008

The vegetation cover decreased from 1996 (69.79%) to 2008 (55.21%) see Table 1. There was a decrease of 796.7ha which translates to 66.4ha/yr. Table 4.0.6 show that from the interviewed 80% believed that the forest has depleted and some of the reasons being primitive harvesting techniques and harvested forest produce preservation techniques. [1] in their study in Mafungautsi noticed 115 bundles of thatch grass rotting in Batanai at the treasury's homestead in April 2001 and at the Chairman's homestead in Chimwero – Masawi although the exact number could not be counted due to advanced rotting. Vegetation cover has been affected as seen on the Vegetation Cover Map of

2008 (Figure 6) especially on the South – Western side of the forest and the Southern side have been cleared for settlement purposes. There is an increase in spatial extend of the cleared area with respect to the time series. The vegetation cover of 2008 was heavily depleted due to settlements within the forest that has Kalahari sands that are of a low nutrient value and forces farmers to practice shifting cultivation that forces periodic clearing of the forest area. (14) found that soil organic matter in the Mafungautsi Kalahari sands declines rapidly after cultivation and no meaningful crop production can be achieved after five to ten years of crop production without inputs of manure or fertilizer. Therefore shifting cultivation has an impact on vegetation cover and the forest structure.

[8] states that, "the generation of economic benefits, for example, is often an essential incentive for conservation, but increasing resource-based revenues can also stimulate increased local competition and potentially concentration of benefits".

The study carried out by [9] the Fast Track Land Reform Program FTLRP put pressure to RMCs as members who had been managing the forest felt the invaders have to be evicted, failure to do so lead to villagers invading the forest.

RECOMMENDATIONS

Often there is a contradiction in forest resource use and their maintenance. For example, harvesting bark for medicinal purposes or wood for carving or harvesting of wild fruits sometimes involves destructive harvesting practices that impact on the plant populations being harvested [10]. In these circumstances highly sought plant species may fail to sustain harvesting pressure and eventually undergo losses in population numbers (15). Vegetation changes are imminent where there is forest resources exploitation. There is need for a research on how the decrease in vegetation cover has affected species density and species richness. There are factors like timber poaching that favor certain species over others so permanent sample plots can be tagged in areas were the preferred species are abundant and a species register database is constructed. Periodic reviewing of such sample plots can be instrumental in vegetation monitoring and for inventory purposes that in turn provide information to policy makers. Biodiversity studies also need to be undertaken on how the vegetation cover change is affecting ecological functions and different trophic levels. There is need to evaluate if there are species that can be under threat from resources exploitation.

Soil scientist and agriculturalists must to a large extent sample and analyze the soil nutrient value and come up with areas that can be allocated for resettlement and put in place measures that do

away with shifting cultivation. The best farming practices must be implemented by farmers for land conservation. The settlers can be in cooperated in the CBNRM with a distinct code of action that should be adhered to and failure not to can lead to prosecution from the relevant authorities.

CBNRM approaches differ with respect to variable in a specific locality. Therefore there is need for a detailed analysis on the best model that is relevant and effective in the management of the forestry resources in Mafungautsi. The model should factor in tenurial rights that enable communities to conserve that destroy; autonomy; preferred course of action; political landscape; and the course of action. CBNRM should not just be adopted because there have been successful elsewhere but they need to have relevancy in their area of implementation with respect to uniqueness of those areas.

CONCLUSION

In the 1990s conservation practices were to a large extent were extent successful but with the coming of the new millennium there were several challenges in CBNRM for example the withdrawal of donour funding and agricultural activities taking precedence within the forest area. The change detection study discovered that vegetation cover decrease within Mafungautsi. Vegetation cover change was mostly attributed to institutional poverty and conflicting policies (conservation versus agriculture). Policies need to be complimentary during policy formulation and implementation so as to achieve the intended institutional goals. There is need to model CBNRM approaches to suit the variables of the area of implementation for conservation to be realized and ensuring sustainable development. There is need to evaluate the direction a project is taking over time and in this case vegetation change detection is an essential part for continual improvement. The change detection information is essential for lessons learnt so that the same mistakes will not be repeated when the program is implemented elsewhere. Evaluating the performance of a project is essential for capacity building and adaptive management of the management committees.

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A review of automation systems for the optimization of diamond processing technologies.

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ABSTRACT

Zimbabwe is in the process of setting up a national diamond processing technology centre, whose main objective is to add commercial value to the diamond mining industry. Through this new technology centre, vast downstream employment opportunities will be created, infrastructural development will take place and socio-economic lifestyles at household level will improve. It is, therefore, the aim of this study to analyze the level of scientific and technological preparedness within Zimbabwe in comparison to other global diamond processing industries *(e.g. Surat & Gujarat Province in India, Guangdong & Shandong in China, Brugge in Belgium,Venice, Florence & Genoa, etc.)* and in turn proffer solutions for the advancement of both skills and technology development in meeting the demands of this new industry. It is intended that the data accumulated should be institutionalized, analyzed and translated into information accessible to stakeholders and decision-makers. We present a case that illustrates the infrastructural needs and challenges for long term research and then discuss optimal designs and collaborations required to detect change in many variables, processing technology use types, previous and current universal consumer patterns of diamond related finished products and make inferences on future trends. In 2009, research conducted by *MSNBC* showed that India spent US$10/ct in polishing and cutting diamonds while *China* spent US$17/ct on the same activities and *South Africa*, *Zimbabwe's* immediate neighbour, spent between US$40 to US$60/ct. These variations arise from the types of the processing technologies used, hence the need to impress upon the improvement and innovation on the automated control engineering systems in-order to reduce the processing cost ratio per carat of diamond.

Key Words: diamond processing, technologies, mining industry, policy, engineering systems.

INTRODUCTION

From the diamond mining regions of Africa, to the hands of skilled cutters and polishers in Asia[18] and to the retailers in the West[40], this is the diamond's global path to the market. Trading in gem-

grade rough diamonds is primarily controlled by *De Beers, Trans Hex, Rio Tinto, BHP Billiton* and a hand-full of other companies which use their cartel power[41] to control the price and supply of diamonds on the wholesale market, Figure 1, thereby controlling and stabilizing prices. Unlike precious metals such as gold, silver or platinum, there is usually a substantial mark-up in the retail sale price of diamonds. There is a limited market for the resale of diamonds that are less than "*investment grade*", hence, rough diamonds are sent directly from *De Beers* mining operations in Africa[9], or secondary mining producers in Canada and Russia to *De Beers'Diamond Trading Company (DTC)* in London, Gaborone, Kimberly and Windhoek, for sorting and resale. The rough stones are separated into 16 000 categories based on size, color and quality, then divided by human or automated sorters into individual lots called "*boxes*". The *DTC* is part of the *De Beers* Group supply chain known as the *Central Selling Organisation (CSO),* which combines ("aggregating") supplies of rough diamonds from multiple sources into one wholesale market[34].

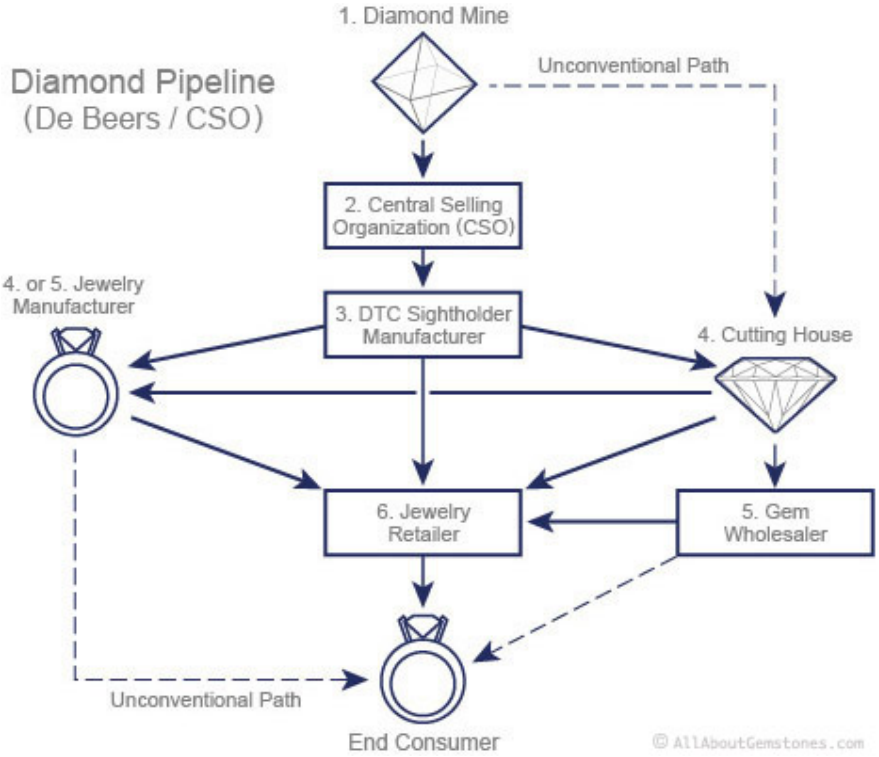


Figure 1: The global market chain of the diamond web.

The *DTC* holds a sale called a "*site*" or "*sight*" ten times per year in London and Johannesburg, where *De Beers* sells the "*boxes"* to its select group of 125 *sightholders*[48] or diamond manufacturers, cutters, and retailers[40]. *De Beers* (*DTC*) sets the price of each box in advance, determining the quantity and quality that each site-holder will receive. A '*sight*' can have a value of between US$500 000 to US$2 000 000.

The sightholder then transports the box of rough diamonds back to cutting and polishing factories located around the world[41]. Many Sightholders are also cutters. Rough diamonds are cut in various geographic regions according to tradition and the skill-sets of the labour force. India cuts the vast majority of small stones (0.20 carats or less) in Mumbai and Surat[3], while large stones are primarily cut in Antwerp, Tel Aviv, Ramat Gan, and New York[18]. Other major cutting centres are located in South Africa, China, Russia, Israel, USA and Thailand. An estimated 92% by pieces 55% by value of the world's diamonds are cut and polished in Surat, an industrial city in western India. It processes 11 out of 12 diamonds in jewellery worldwide. This has helped create close to 1.3 million jobs and accounts for 14% of India's US$80 billion annual exports[5,7]. Bangalore, the symbol of India's knowledge economy, may be a global buzzword, but the fate of India's rural poor depends more on industrial cities like Surat. Many say the first diamond was discovered 4,000 years ago in the shining sands of an Indian riverbed in the Golconda region (modern-day Hyderabad)[3]. Adventurers made similar discoveries in South Africa's dusty veldt in the 19th century. Today, India dominates the polishing business, although the country produces no raw diamonds of its own. It is the highly skilled yet cheap workforce that has made India one of the major players in the industry, contributing to the country's rapid economic growth.

On the other hand, India spends US$10 per carat on the polishing and cutting of diamonds, against China's US$17 and South Africa's expenditure which ranges between US$40 to US$60. However, India is said to be gearing up to cash in on this competitive edge to maintain its position as the world's largest diamond-cutting and -polishing centre, but, most of these diamonds currently pass through diamond-selling centres in Israel, Belgium and elsewhere before ultimately reaching India. Meanwhile, the Indian government has been trying to ensure a continuous flow of rough diamonds through companies like *De Beers* and *Rio Tinto Group*. Even though there are many companies that are clients of *De Beers*, Indian diamond merchants cannot procure the best stones directly from rough-producing nations or even big companies like *Alrosa* of Russia. Comparatively, many Indian exporters are hoping to change that by actively persuing their objective of direct procurement of rough diamonds from mining companies in Russia, Canada, Angola, Liberia and Sierra Leone. This will not only cut costs, but will help India become a diamond trading hub instead of just a manufacturing hub. Some Indian traders fear that they will be left with small stones while the bigger, better stones will be polished in the producing countries of Africa, or as is the case now, in Antwerp, Belgium, and New York. At the same time, diamond-producing nations are no longer content with just mining the rough diamonds. They want to cut and polish them, too. African cutters may now cut into India’s profits.

The Indian diamond trade, dominated by the close-knit *Palanpuri Jain* community, is now eyeing bigger, pricier stones[2]. Surat companies are now setting up branches in New York and Tel Aviv, Israel, and learning from cutters in Belgium and Israel. Indian diamond merchants are also trying to secure a foothold in the lucrative Chinese market[8], where the burgeoning middle class is developing a taste for diamonds[12]. However, once diamonds are cut and polished, they are then resold to wholesalers (*Diamond Bourses*)[9], or to jewellery manufacturers[11,40] around the world. Both traders and manufacturers may sell diamonds "upstream" and "downstream" through the diamond pipeline[50], to take advantage of market fluctuations. Once the diamonds are set into jewellery, they are sold to retailers or direct to the customer. However, *De Beers' (CSO's)* control over the wholesale diamond market has diminished due to increased market penetration, and the breakaway from *CSO's* cartel by the *Argyle Diamond mine* in Australia[47], and independent diamond producers in Canada, Russia and elsewhere. As a reaction to their decrease in market share, *De Beers*, through its *Diamond Promotion Service (DPS)* and *Diamond Information Centre (DIC)* marketing divisions, has launched an aggressive branding and marketing campaign of reclamation codenamed "*A Diamond Is Forever*" moniker[42]. Hence, Zimbabwe as an emerging diamond market, has the potential of investing heavily in diamond beneficiation, establishment of diamond processing state-of-the-art technologies, and as well as human capital development through well organized, intensive and targeted research.

Basic physical properties of diamond

Diamond is the hardest naturally occurring material on earth, with a relative hardness of 10 on the *Moh's* scaleand is one of several allotropes of carbon, with the principal allotrope being graphite. At the same time, diamond is a transparent, optically isotropic crystal with a high dispersion of 0.044, a refractive index (RI) of 2.42, and a specific gravity of 3.52. The unique chemical and molecular structure of crystalline diamond is what gives this gemstone its hardness, and differentiates it from simple graphite[26]. A type II-A diamond has a hardness value of 167 *Gpa* (±6) when scratched with an *ultrahard fullerite tip*, and a hardness value of 231 *Gpa* (±5) when scratched with a diamond tip[19]. A diamond's incredible hardness was the subject of curiosity dating back to the Roman empire[3], where it was shown to combust in scientific experiments, although the reason for its combustion was not understood at the time. Experimentation during the late 18th century demonstrated that diamonds were made of carbon, by igniting a diamond in an oxygen atmosphere, with the end byproduct of the combustion being carbonic-acid gas, or carbon-dioxide

gas. Diamond has a predictable crystal habit which is orderly and symmetrical. The natural crystal habit is octahedral (Figure 2) although in nature, perfectly formed crystals are rare.

Figure 2: Characteristic crystalline structure of diamond

The external shape of the crystal, whether it is cubic, octahedral (Figure 3), or dodecahedral (Figure 4), does not always reflect the internal arrangement of its atoms. An irregular external gem-stone shape is *subhedral* or *anhedral.* However, within the fields of metallurgy and material science, the term ***toughness*** describes the resistance of a given material to fracture when it is stressed or impacted. Although diamond is the *hardest,* its *toughness* rating is moderate due to its ability to fracture along cleavage planes. Unlike hardness, which only denotes a diamond's high resistance to scratching, a diamond's toughness is only fair to good. Particular cuts of diamond are more prone to breakage along cleavage planes, and therefore may not be insured by reputable insurance companies. The culet facet at the bottom of the pavilion, is a facet specifically designed to resist breakage. Additionally very thin girdles on brilliant cut diamonds are also prone to breakage.

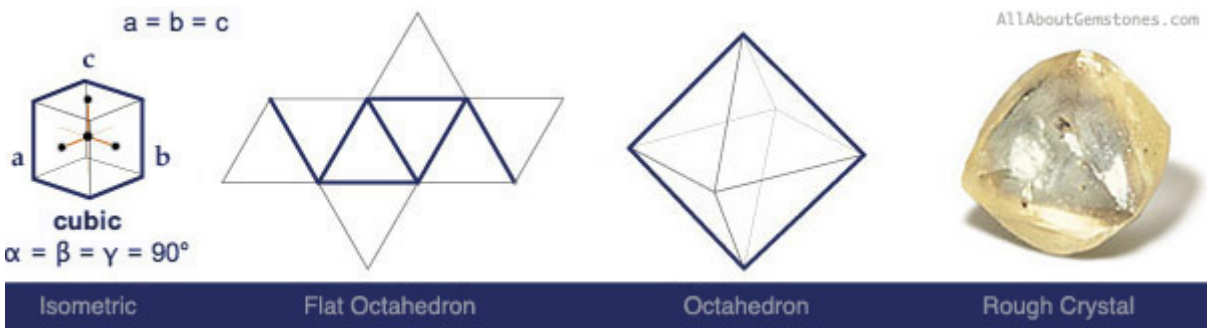


Figure 3: Octahedral shape of diamond.

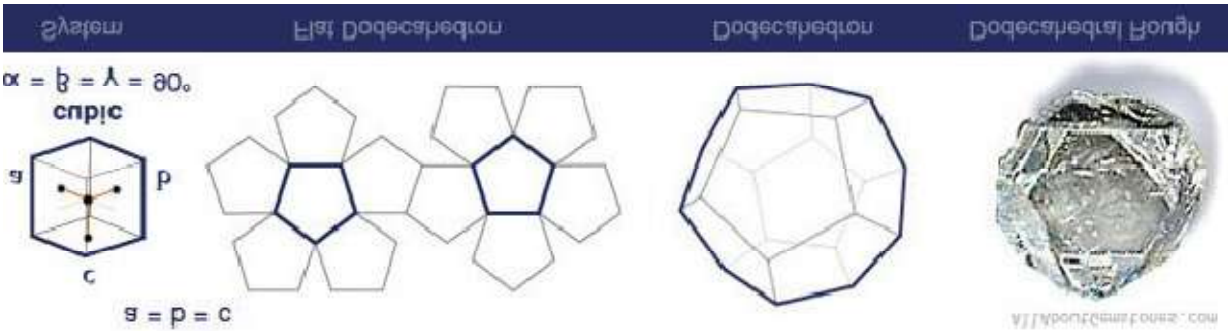


Figure 4: Dodecahedral shape of diamond.

Thermal properties of diamond

Diamond is a good conductor of heat, such that, many natural blue diamonds contain boron atoms which replace carbon atoms within the crystal matrix, thereby, increasing its thermal conductance. By comparison, purified synthetic diamond is found to possess the highest thermal conductivity of between 2000 to 2500 $Wm^{-1}K^{-1}$ in respect of any solid material at room temperature, e.g. it is nearly five times greater than that of pure copper. Due to the diamond's high thermal conductivity, it is also used in the manufacturing of semiconductors, to prevent silicon and other semiconducting materials from overheating.

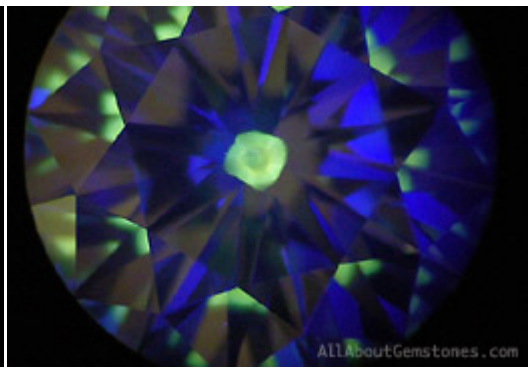
Optical Properties of Diamond

Fluorescence is an optical phenomenon in which a diamond's molecules absorb high-energy photons, re-emitting them as lower-energy, or longer-wavelength photons. Hence, when diamond is exposed to long wave ultra-violet light it gives off a bluish-white, greenish or yellow fluorescence (Figure 5). Some diamond varieties, particularly Canadian diamonds, show no fluorescence, and appear dark when exposed to ultra-violet light or X-rays. However, during the designing of a diamond cut, two primary optical factors are used; i.e. RI and the dispersive power of splitting white light into its component spectral colours, Figure 6. The diamond's RI is responsible for its *brilliance, which* can be divided into two categories, i.e. *external brilliance* and *internal brilliance*. The former is responsible for its *luster*. On the other hand, *scintillation brilliance* occurs as the degree of "sparkle" seen when the stone or observer moves. Scintillation is dependent on the size, number, and symmetry of facets, as well as on quality of polish, such that small stones appear milky due to the limitations of the human *eye*, whereas larger stones appear lifeless if their facets are too large or too few.

(i) Long Wave/Short Wave UV Cabinet

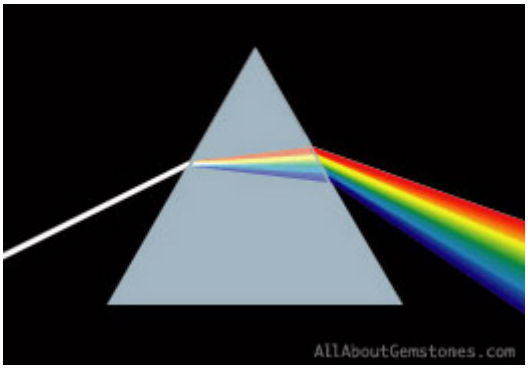
(ii) Diamond Fluorescence Under UV Light

(iii) Cloud Inclusion Under UV



(iv) Type I UV Fluorescence

Figure 5: Fluorescence in diamonds



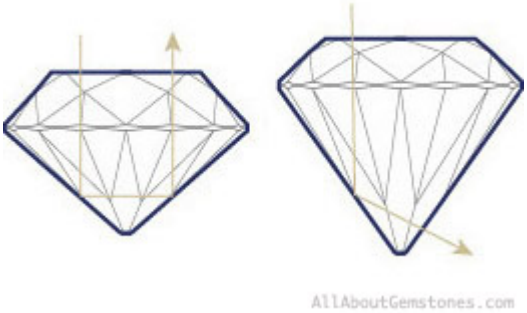


Figure 6: Diamond refraction & light dispersion

Similarly, diamond can exhibit *pseudochromatic*[37], i.e. illusion of colour, caused by the varying optical effects created by *spectral dispersion or fire*, and *refraction.* Diamonds can also exhibit *allochromatic colouration*, caused by *chromophores* from the nitrogen trace impurities found within the crystalline structure. It is this nitrogen component that produces the colour of fancy yellow diamonds.

Physical enhancement of diamonds

Diamond "*enhancements*" are specific treatments performed on cut, polished natural diamonds, which are designed to improve the visual or gemological characteristics of the stone, but not necessarily increase its value.

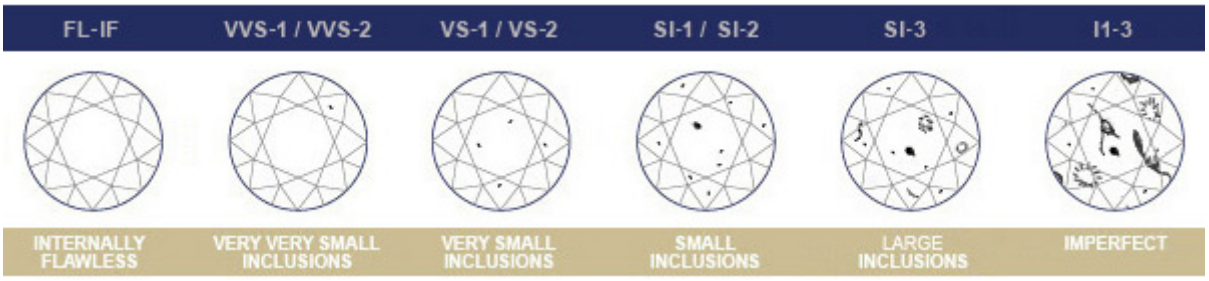


Figure 7: Diamond inclusions

Minor *diamond inclusions*or *surface imperfections* which are not visible to the naked eye *("VVS1" to "SI2", Figure 7)* can be disguised, altered, or removed by employing several invasive techniques from *fracture filling* to *laser drilling*. These techniques do not eliminate the imperfection, but instead attempt to hide their visual effect. There are also heating treatments to improve a white diamond's colour grade, or treatments to give a fancy colour to an off-white diamond. Hence, a trained gemologist must be able to identify most of these traditional enhancements made to a particular stone. Diamonds that have been altered or enhanced by *fracture filling* and/or *laser drilling* should always be labelled and their improvements identified in accordance with the Federal Trade Commission's *(FTC)* guidelines on gem trade.

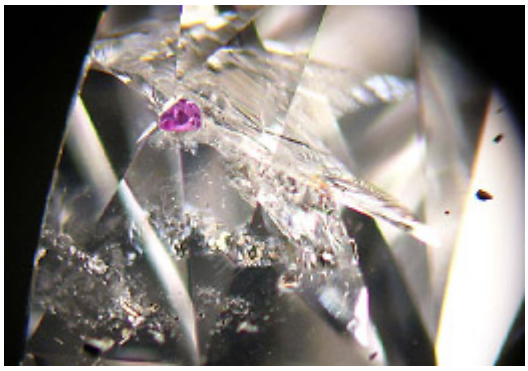
Diamond Fracture Filling

Diamond clarity is sometimes improved and enhanced by filling tiny fractures or feathers with molten glass, much like one would repair a crack in a car's windshield glass. Such diamonds are sometimes then branded as fracture filled diamonds. Reputable filling companies will always use filling agents which show an orange or pink flash of colour when viewed under a microscope with

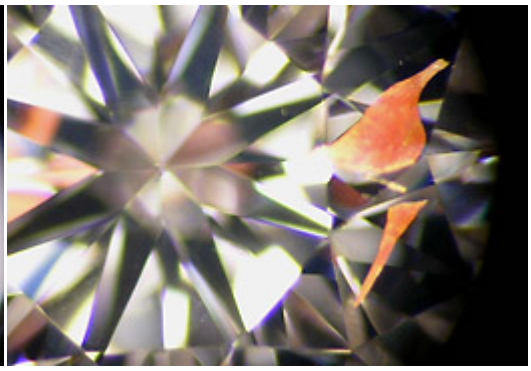
certain controlled lighting conditions. This form of enhancement, however, results in a significant price discount for any diamond that has been fracture-filled, and the GIA will not even grade a fracture-filled diamond, in part because the treatment is not permanent. Due to its low melting-point, the heat generated by a blowtorch used to work on settings can cause damage to the filling material. It is, therefore, essential to inform anyone working on a setting where the diamond has been fracture-filled, so that the jeweler can use greater care while working on the piece. Reputable filling companies will often provide repeat treatments if heat causes damage to the filling.

Diamond laser drilling

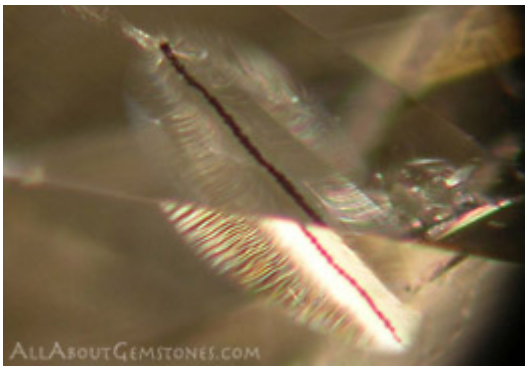
Laser drilling involves the use of a laser to burn a tunnel or hole down to any dark carbon inclusions, followed by acid washing to remove the colouring agent. The drilling process will leave *tiny telltale shafts* or *tunnels* (Figure 8) that are visible under high magnification. The laser-drilling treatment is considered permanent, and both the GIA and AGS will issue grades for laser drilled diamonds. The final clarity grade will be the grade that is assigned after treatment.



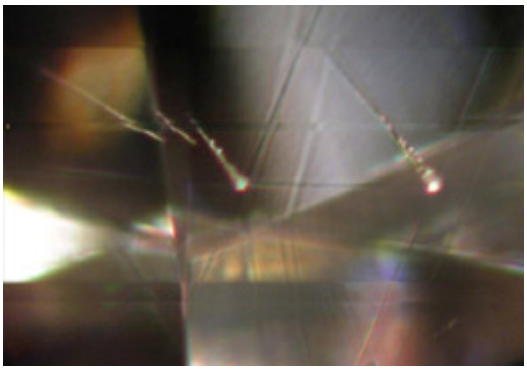
(i) Unfilled fractures around Garnet inclusion.



(ii) Telltale Signs of fracture filling.



(iii) Signs of Laser Drilling.



(iv) Laser Drilling Tubes.

Figure 8: Diamond structural enhancements

Diamond colour treatment

Colour enhancement of diamonds is done to increase the colour intensity of so-called fancy coloured diamonds. These enhancements are achieved using low levels of radiation, or subjecting the diamond to intense pressure and temperature, referred to as the HTHP process.

(i) Natural Fancy Diamonds

(ii) Colour Enhanced Diamonds

Figure 9: Diamond colour enhancements

Radiation treatments are completely safe, and the diamonds are tested to ensure that no trace levels of radiation remain. Diamonds treated with HTHP have their molecular structure altered so that intense vivid blue and yellow colours result.

Modern Diamond Cutting

Most diamond processing factories use sophisticated electronic equipment for cutting and evaluating cut diamonds. Using the latest hardware and software to create highly accurate 3D models, these scanners measure the angle of inclination of a facet and its azimuth, allowing the operator to pre-visualize a 3D model of the cut stone. *HeliumPolish Scanners*, Figure 10, are used for Round Brilliant Cuts as well as Fancy cuts. A device called a *Pacor Oxygen Scanner* can also be used for optimizing rough stones based on purity to evaluate inclusion removal or reorientation.

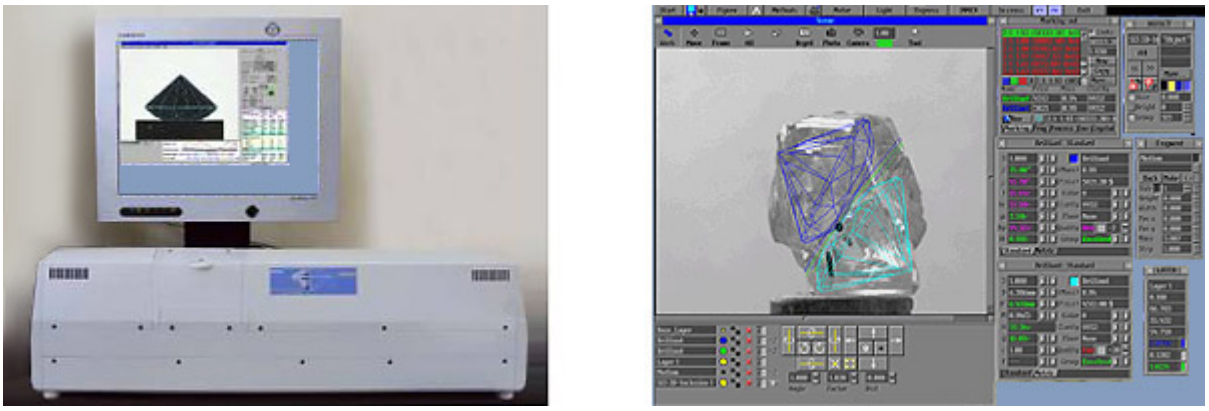


Figure 10: Helium-Polish Scanners

The choice of diamond cut is often decided by the original shape of the rough stone, location of internal flaws or *inclusions*, the preservation of carat weight, and the popularity of certain shapes[2]. The cutter must consider each of these variables before proceeding. Most gem-quality diamond crystals are octahedral in their rough state. These crystals are usually cut into *round brilliants* because it is possible to cut two such stones out of one octahedron with minimal loss of weight. The most common basic diamond shapes are *Emerald, Heart, Marquise, Oval, Pear, Princess, Radiant, Round, Figure 11, and the Trillion* which is not shown.

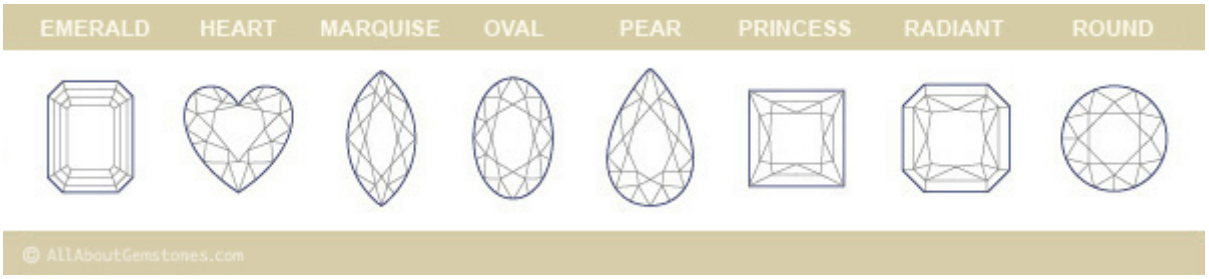


Figure 11: Diamond cuts and shapes

If the crystal is malformed or twinned, or if inclusions are present at inopportune locations, the diamond is more likely to receive a *fancy cut*. This is especially true in the case of *macle*, which are flattened twin octahedron crystals. Popular fancy cuts include the *Barguette (bread loaf)*, *Marquise* or *Navette* (*little boat*), *Princess (square outline*), *Heart, Briolette* (a form of Rose cut), and the *Pear*. The fancy cuts are generally not held to the same strict standards as *Round Brilliants*[33]. Round brilliants have certain requisite proportions which would result in high weight loss, whereas fancy cuts are typically much more flexible in this regard. Sometimes the cutters compromise and accept lesser proportions and symmetry in order to avoid inclusions or to preserve carat weight,

since the per-carat price of diamond is much higher when the stone is over one carat (200 *mg*)[34]. While the round brilliant cut is considered standard for diamond, with its shape and proportions nearly constant, the choice of fancy cut is influenced heavily by fashion. For example, the *step cutbaguette,* accentuates a diamond's luster, whiteness, and clarity but downplays its fire, whilst the *mixedPrincess cut*, accentuates a diamond's fire and brilliance rather than its luster and is currently gaining popularity[4]. The princess cut is also popular amongst diamond cutters because it wastes the least of the original crystal. Older diamonds cut before ca. 1900 were cut in "primitive" versions of the modern round brilliant, such as the *rose cut* and *old mine cut*. Although there is a market for antique stones, many are recut into modern brilliants to increase their marketability[19]. There is also increasing demand for diamonds to be cut in older styles for the purpose of repairing or reproducing antique jewellery.

Meanwhile, cutting a rough diamond into a faceted and polished gem-quality stone is a multi-step process, which involves;

Marking: A rough stone is marked prior to cleaving or sawing to determine the direction of the grain and cleavage, to eliminate waste, and bypass any inclusions and imperfections. High-tech computerized helium such as the *Poly-Metric Scintillator 88 Digital* and the *Facetron* machines, Figure 12, are semi-automated and used for eliminating some of the guess-work in stone cutting. However, a highly skilled craftsman must cut a rough stone to its optimal size, by examining it under a Loupe and decide on the type of cut that will show the stone's best attributes. These machines are water-cooled and designed to make cuts at precise angles by mathematically plotting out to depth and degree of a given facet up to a certain tolerance. The rough gemstone is held by a chuck called a dop, to which it is held with hot-wax glue.

Fig. 12 Poly-Metric Scintillator 88 Digital & the Facetron

Cleaving: Cleaving refers to splitting a stone along its grain by striking it. A rough stone is cleaved if there are conspicuous defects and/or inclusions which would prevent it from being made into a single gemstone. Due to its atomic structure, a diamond can be cleaved in four directions parallel to each of the four octahedron crystal faces. Cleaving is a critical step as any mistake by the cleaver could fracture or shatter the stone.

Sawing: A stone-cutting saw is a thin disk made of phosphor bronze. As the saw bladerotates it continues to pickup or recharge itself with diamond dust which is the cutting agent. It can take several hours for the saw blade to cut through a 1K rough diamond[18]. The images in Figure 13 show a rough gemstone attached to a dop stick, a combination lapidary gemstone saw and grinder.

Figure 13: Dop stick attachment & Lapidary gemstone saw

Bruting (Girdling)

The rough diamond is placed in a chuck on a lathe where it rotates, whilst a second diamond mounted on a dop is pressed against it, rounding the rough diamond into a conical shape. AutoBruters, Figure 14, use the latest technology to preform "non-contact" measuring to overcome inherent problems in the rounding process.

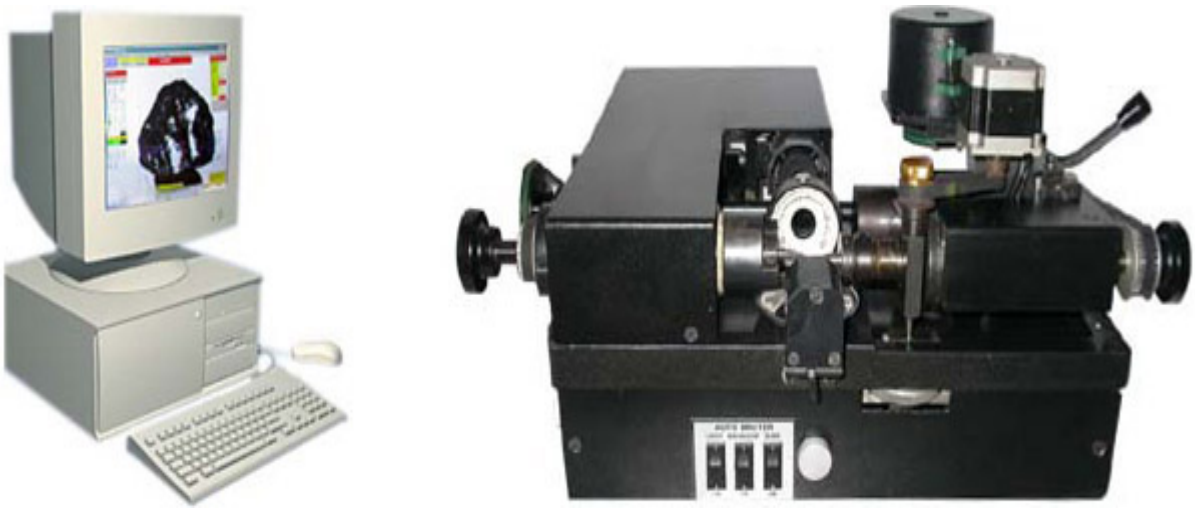


Figure 14: AutoBruters

Facetting

To facet a round brilliant, the blocker or lapper will cut the first 18 main facets, then a *brillanteer* will cut and polish the remaining 40 facets. The cutting and polishing (Figure 16) of each facet is accomplished by attaching the stone to a dop stick with cement (Figure 15), then pressing it against a revolving cast iron disk, on a *scaife* or lap that has been charged with diamond dust. During this faceting stage the angles of each facet must be cut to an exacting standard in order to yield maximum brilliance, and maintain symmetry.

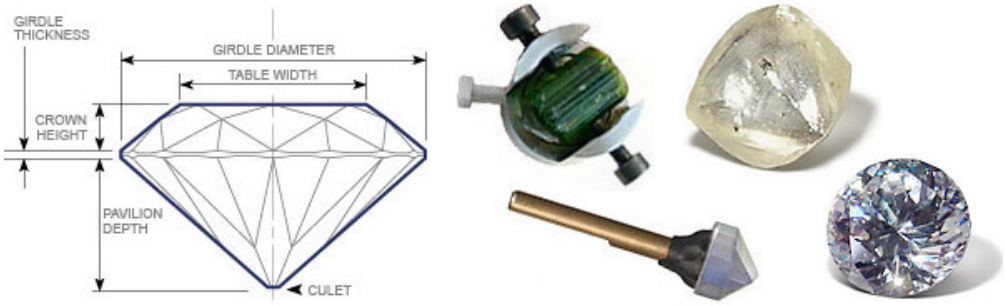


Figure 15: Diamond Proportions

Figure 16: Cabochon Grinder for gem polishing.

Diamond grading characteristics

There are four main characteristics for grading both rough and cut diamonds[28], i.e.

(i) Cut.

(ii) Carat.

(iii) Clarity.

(iv) Colour.

Cut

The history of diamond cuts can be traced to the late Middle Ages. The first improvements on nature's design involved a simple polishing of the octahedral crystal faces to create even and unblemished facets, or to fashion the desired octahedral shape out of an otherwise unappealing piece of rough, called the point cut. By the mid 15th century, the point cut began to be improved upon as just one half of the octahedron would be sawn off whilst creating the table cut. In or around 1476, *Lodewyk van Berquem*, a Flemish polisher of Bruges, introduced absolute symmetry in the disposition of facets[17]. He cut stones in the shape known as *pendeloque* or briolette; these were pear-shaped with triangular facets on both sides. About the middle of the 16th century, the rose or rosette was introduced in Antwerp[31]: it consisted of triangular facets arranged in a symmetrical radiating pattern, but with the bottom of the stone left flat, essentially a crown without a pavilion. Many large, famous Indian diamonds of old, such as the *Orloff* and *Sancy*, also feature a rose-like cut and some suggest that Western cutters were influenced by Indian stones. However, Indian "rose cuts" were far less symmetrical as their cutters had the primary interest of conserving carat

weight, due to the divine status of diamond in India[3]. In either event, the rose cut continued to evolve, with its depth, number and arrangements of facets being tweaked.

The first brilliant cuts were introduced in the middle of the 17th century. Known as *Mazarins*, they had 17 facets on the crown (upper half). *Vincent Peruzzi,* a Venetian polisher, later increased the number of crown facets from 17 to 33, thereby significantly increasing the fire and brilliance of the cut gem, properties which in the Mazarin were already incomparably better than in the rose. Yet Peruzzi-cut diamonds, when seen nowadays, seem exceedingly dull compared to modern-cut brilliants. Because the practice of *bruting* had not yet been developed, these early brilliants were all rounded squares or rectangles in cross-section.

Around 1900, the development of diamond saws and good jewellry lathes enabled the development of modern diamond cutting and diamond cuts, chief among them the *round brilliant* cut. In 1919, *Marcel Tolkowsky*analyzed this cut[16]: his calculations took both *brilliance* and fire into consideration, creating a delicate balance between the two. Tolkowsky's calculations became the basis for all future brilliant cut modifications and standards. Tolkowsky's model of the "ideal" cut is not perfect. The original model served as a general guideline, and did not explore or account for several aspects of diamond cut. Another important point to consider is that *Tolkowsky* did not follow the path of a ray that was reflected more than twice in the diamond[22]. However, we now know that a diamond's appearance is composed of many light paths that reflect considerably more than two times within that diamond. In the 1970s, *Bruce Harding* developed another mathematical model for gem design[26]. Since then, several groups have used computer models and specialized scopes to design diamond cuts. Hence, the desire to do further research and development on better and efficient methods for diamond cutting in Zimbabwe, thereby reducing the cost ratio per carat.

As a result of this concern, some players in the industry tend to confuse a diamond's cut with it's shape[25]. Shape refers only to the outward appearance of the diamond (Figure 11) and not how it is faceted. When a diamond has a high quality cut, incident light will enter the stone through the table and crown, travelling toward the pavilion where it reflects from one side to the other before bouncing back out of the diamond's table towards the observer's eye (Figure 17). This phenomenon is referred to as light return (Figure 18) which affects a diamond's brightness, brilliance and dispersion. Any light-leakage caused by poor symmetry and/or cut proportions will adversely affect the quality of light return. The Shallow Cut and Deep Cut examples in Figure 17 show how light

that enters through the table of a Modern Round Brilliant diamond reaches the pavilion facets and then leaks out from the sides or bottom of the diamond rather than reflecting back to the eye through the table. Less light reflected back to the eye means less Brilliance. In the Ideal Cut example, most of the light entering through the table is reflected back towards the observer from the pavilion facets.

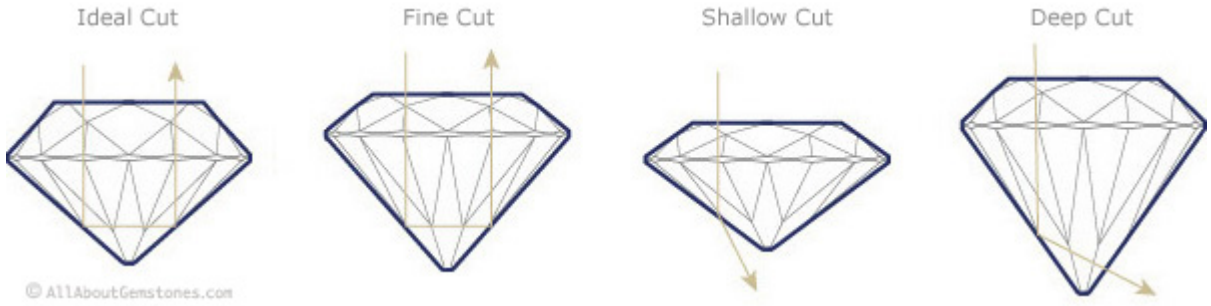


Figure 17: Cut quality classification

The variance in proportions between an ideal cut, premium cut, very good or fine cut, good cut, and a fair, poor, shallow or deep cut may be difficult to discern to the novice observer, although there will be a lack of brilliance, scintillation and fire. In the past, the quality of the cut was a very difficult characteristic to ascertain when classifying a good diamond because of the fact that a GIA or AGS certificate did not show the important measurements (Table 1) that tend to influence a cut (i.e. pavilion and crown angle) and did not provide a subjective ranking of how good the cut was, however, current reports do indicate these parameters[29].

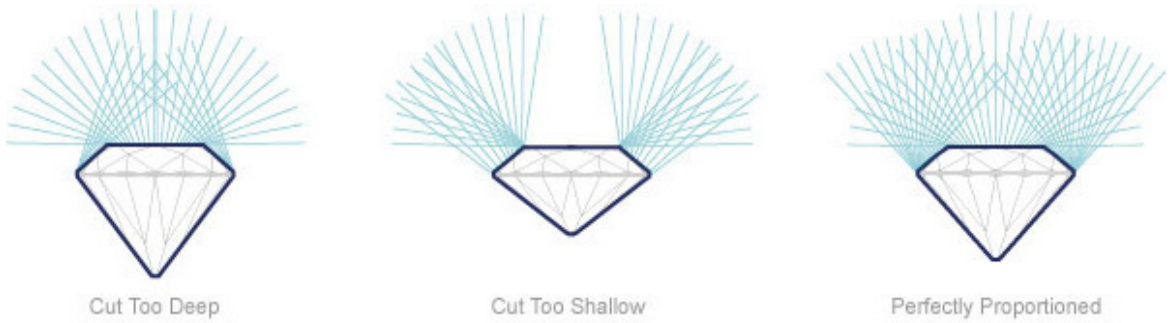


Figure18: Effect of "light return" on diamond's brightness, brilliance and dispersion.

Table1: Basic proportions of an ideal cut

	Table size	53 to 60 % of the diameter.
	Depth	58 to 63 % of the diameter.
	Crown angle	34 to 35 degrees.
	Girdle thickness	Medium to slightly thick.
	Facets	58 (57 if the culet is excluded)
	Polish & Symmetry	Very good to excellent.

The modern round brilliant consists of 58 facets (or 57 if the culet is excluded); 33 on the *crown* and 25 on the *pavilion*[24,37], Figure 15. The girdle may be frosted, polished smooth, or faceted and can have 32, 64, 80, or 96 facets which are not counted in the total number of facets of 58. Common cutting problems can occur during the faceting process, where one incorrect facet angle can throw off the symmetry of the entire stone. This can also result in the undesirable creation of extra facets beyond the required 58, Figure 19, shows several common problems to look for during this process.

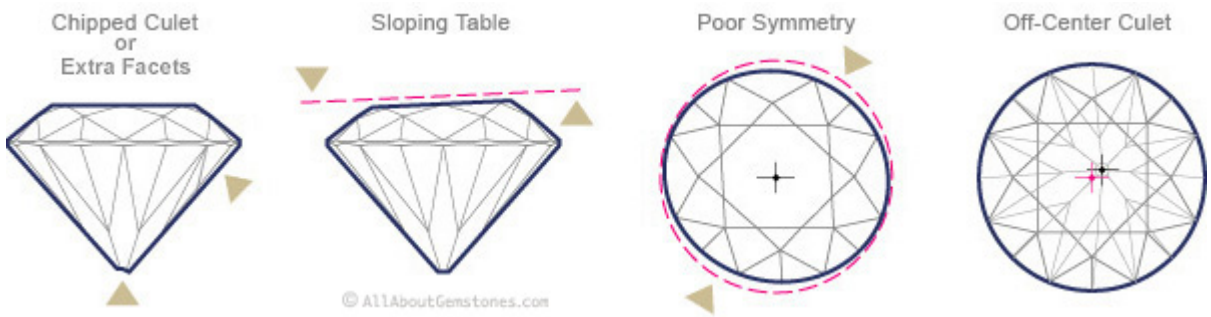


Figure 19: Poor diamond faceting and symmetry.

Likewise, some diamonds may have small extra facets on the crown or pavilion that were created to remove surface imperfections during the diamond cutting process. Depending on their size and location, they may hurt the symmetry of the cut and are therefore considered during cut grading. While the facet count is standard, the actual proportions, *crown height* and *crown angle*, *pavilion depth* and *pavilion angle*, and *table size,* are not universally agreed upon. There are at least six "ideal cuts" that have been devised over the years, but only three are in common use as a means of benchmarking, i.e. the *American Standard,* derived from mathematical calculations that considered both brilliance and fire; the *Practical Fine Cut* or the *Feinschliff der Praxis,* developed in Germany by empirical observations; and the Scandinavian Diamond Nomenclature. The Eulitz[22] cut is the

only other mathematically-derived benchmark; it is also historically the only benchmark to consider girdle thickness. A more modern benchmark is that set by Accredited Gem Appraisers (AGA), but has been criticised for being too strict. A summary of the different benchmarks is given in Table 2

Table 2: Different "ideal cut" benchmarks.

Benchmark	Crown height	Pavilion depth	Table diameter	Girdle thickness	Crown angle	Pavilion angle	Brilliance Grade
American Standard	16.2%	43.1%	53.0 %	N/A	34.5°	40.75°	99.5 %
Practical Fine Cut	14.4%	43.2%	56.0 %	N/A	33.2°	40.8°	99.95 %
Scandinavian Standard	14.6%	43.1%	57.5 %	N/A	34.5°	40.75°	99.5 %
Eulitz Brilliant	14.45 %	43.15 %	56.5 %	1.5%	33.36°	40.48°	100%
AGA	14.0-16.3%	42.8-43.2%	53-59%	N/A	34.0-34.7°	N/A	100%

Meanwhile, in a perfectly proportioned ideal cut that is cut to the exacting specifications of these benchmarks, it will display a Hearts and Arrows pattern (Figure 21) when observed through an *Idealscope* or an *H & A Viewer gemscope (Firescope),* Figure 20 (left). This viewer uses a 10x lens with a pink/red reflector positioned in front of the diamond under a central viewing hole, allowing the viewer to see how much of the red/pink light refracts back from the diamond. The resulting pattern will be a good indicator of faceting proportion and symmetry. For performing Cut Analysis on the finished stone, a *Dia-Analyser*, Figure 20 (right), uses a camera to take photographs of the finished diamond while it is being rotated. The computer's software will digitize and then analyze the data to quantify all of the cut parameters.

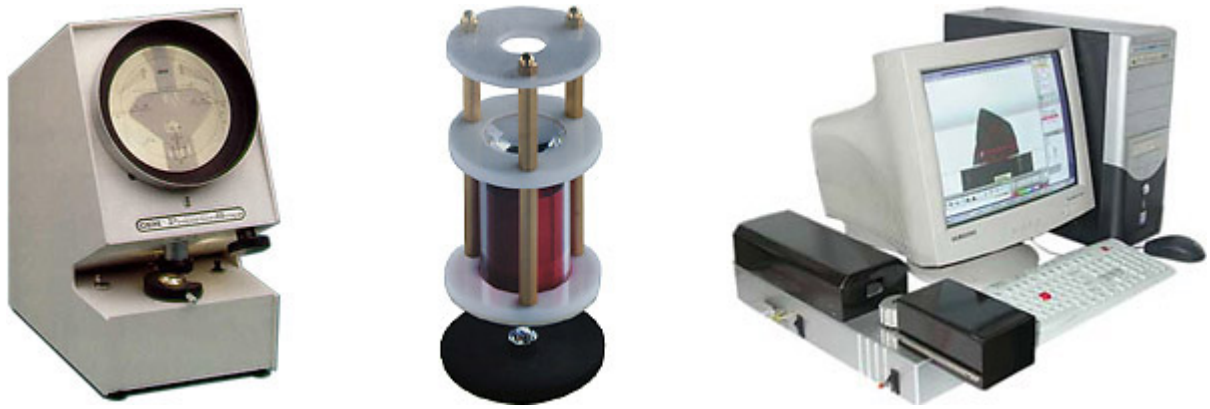


Figure 20: An Idealscope and Computerized Dia-Analyzer for Cut Analysis

A. Perfectly Formed B. Imperfect

Fig. 21 Hearts and Arrows Diamonds

Carat weight

A diamond or gemstone's carat designation is a measurement of both the size and weight of the stone. One carat is a unit of mass that is equal to 0.2 grams (200 mg or 3.086 grains) or 0.007 ounce. A carat can also be divided into points with one carat being equal to 100 points, and with each point being 2mg in weight. Therefore, a ½ carat diamond would be 50 points, a ¾ carat diamond is 75 points, and a 2 carat diamond is 200 points. When a single piece of jewellery has multiple stones, the total mass of all diamonds or gemstones is referred to as *Total Carat Weight* (TCW).

Figure 22: Carat/millimeter sizing chart for comparison purposes only.

Occasionally, a stone cutter will need to make compromises by accepting imperfect proportions and/or symmetry in order to avoid noticeable inclusions, or to preserve the carat rating of the rough stone. Since, the per-carat price of diamond is much higher when the stone is over one carat[34], many one carat diamonds are the result of compromising cut quality to increase carat weight. It is for this reason that an even 1.00 carat diamond may be a poorly cut stone. Some jewellery experts advise consumers to purchase a 0.99 carat diamond for its better price, or to buy a 1.10 carat diamond for its better cut. The apparent size of a diamond is known as its *spread. By sacrificing cut* proportions and symmetry, a diamond can have a larger diameter and therefore, a larger apparent size for a given carat weight, Figure 22. The spread is the ratio between diameter and three principal geometric components, namely crown, girdle and pavilion. A given diamond will have a zero spread penalty if the correct ideal cut symmetry of a 32.5^{o} crown, 40° pavilion, 58% table and 1% girdle are maintained. According to FTC, if the carat weight is shown as 0.20 carat, this could represent a diamond that weighs between 0.195 to 0.204 carat. If the carat weight is shown as one decimal place, it must be accurate to the second decimal place. A diamond that has a specified carat weight of 0.5 carats must have an actual weight of between 0.495 carats and 0.504 carats.

Clarity

The term "Clarity" refers to the presence or absence of tiny imperfections within and/or on the surface of the stone. All of the sub-grades on diamond clarity, Table 3, reflect on the appearance of inclusions within the stone when viewed from above at 10X magnification, whilst higher magnifications and viewing from other angles are also used during the grading process. In colourness diamonds, darker inclusions will tend to create the most significant drop in clarity grade. In fancy-coloured diamonds, light or pale inclusions may show greater relief, making them more apparent, causing a greater drop in grade.

Table 3: Diamond Clarity Designations.

	FL	**Flawless, no inclusions at 10x magnification.**
	IF	Internally flawless, no inclusions at 10x mag.-small blemishes.
	VVS-1	**Very very small inclusions hard to see at 10x magnification.**
	VVS-2	Very very small inclusions. VVS-1 better than VVS-2.
	VS-1	**Very small inclusions, visible at 10x mag. –not naked eye.**
	VS-2	Very small inclusions. VS-1 is better grade than VS-2.
	SI-1	**Small or Slight Inclusions Imperfections may be eye clean.**
	SI-2	Small or Slight Inclusions or Imperfections visible to naked eye.
	SI-3	**Inclusions large and obvious, little or no brilliance.**
0	I-1 to I-13	Imperfect, with large inclusions, fractures, and flaws.

If we recall Figure 7 on diamond enhancements and apply the GIA grading system on inclusions and imperfections, considerations in grading the clarity of a diamond will then include the type of stone, point size and the location of inclusions. Inclusions that are near to, or break the surface, may weaken the diamond structurally, therefore reducing its value significantly. On the other hand, it may be possible to hide certain inclusions behind the setting of the diamond, thus minimizing any negative impact of the inclusion. However, a fairly common practice in the jewellery trade is grade-inflation or grade bumping. According to FTC, a diamond must be within one clarity grade of its advertised amount at the time of sale. If a jeweller sells a diamond that has an actual grade of VS-1, he or she could legally sell it as a VVS-2[34,36]. On the other hand, where SI-3 is used for grading, a designation which was popularized by the European Gemological Laboratory (EGL) grading office, and which neither the GIA nor the American Gemological Society (AGS), the most reputable well known US labs, assign, as it is known that diamonds of this type are of low grade and therefore would be inappropriate for the jewellery industry.

Colour

In determining the colour rating of a diamond, the GIA uses a scale of D to Z in which D is total colourless and Z is yellow. The colour chart in Figure 23 and Table 4 explain the GIA grading system for clear, not fancy-coloured stones.

Table 4: Diamond colour designations

1	**D, E, F**	**colourless(white)**
2	G,H,I,J	near colourless
3	**K, L, M**	**faint yellow or brown**
4	N, O, P, Q, R	very light yellow or brown
5	**S, T, U, V, W, X, Y, Z**	**light yellow or brown**

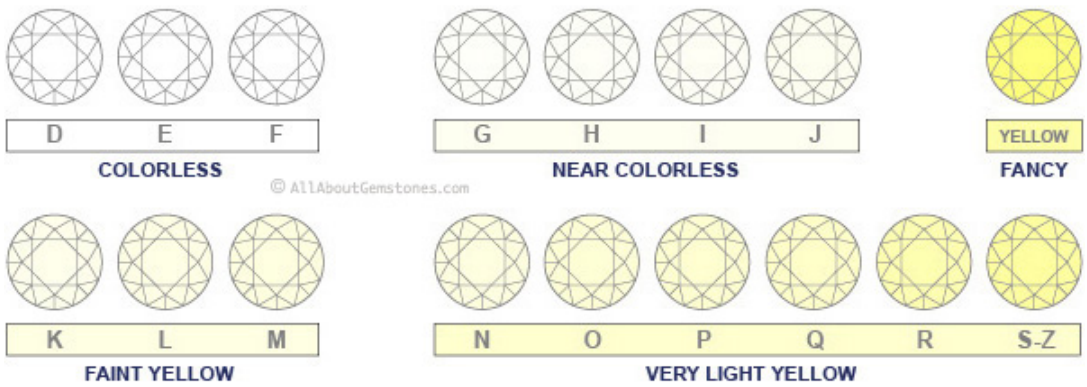


Figure 23: Diamond colour chart

Due to a diamond's high brilliance, and dispersion of light when looking through the table or crown, colour grading should be detetrmined by examining the stone through the side of the pavilion, Figure 24, and not by looking at the top of the stone, Figure 25. Colour grading by visual observation is performed against a *Master CZ Coloured Grading Set*. Meanwhile, S*arin colour typing* is a relatively new sub-classification of the D through Z grading scale. Each classification is divided into five sub-classifications (D1, D2, D3, D4 and D5). Using a Sarin *Diamond Colourimeter DC3000* (or Gran Colourimeter), jewellers and gem labs can accurately provide a colour typing printout of a diamond's colour grading that is compatible with AGS, GIA-GEM, IGI, and HRD grading scales. However, it is extremely beneficial to know if the F grade is a strong F or a borderline G. Unfortunately, most gem labs do not currently provide colour typing data in their reports and certificates.

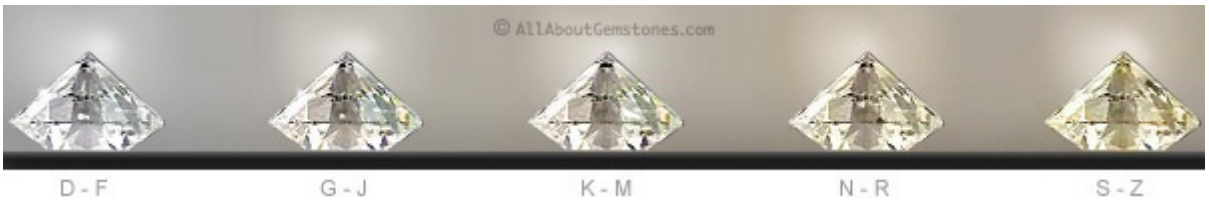


Figure 24:Pavilion side colour view of a diamond.

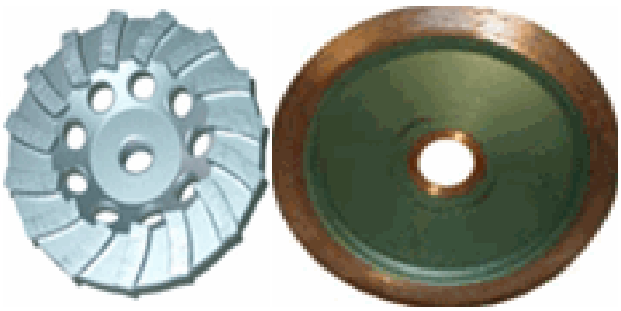
Figure 25: Top colour view of a diamond.

Samples of products manufactured through diamond beneficiation.

(i) Super All-purpose premium blades.

(ii) Continues Rim Diamond Blades.

(iii) Wet and Dry polishing pads.



(iv) Diamond cup wheel & Crack chasing wheels.

v) jewellery

(vi) Drills, bearings, wheels and arbor extenders.

Diamond based electron devices

Diamond is characterized by high mobility of electrons and holes, thereby promising a wide spectrum of applications in electron devices, biosensors, tools and optical parts. In particular, the performance of a diamond semiconductor-based power device is 15 000 times as good as that of silicon semiconductor, and 10 times that of silicon carbide semiconductor[1,15]. While silicon begins to show severe signs of thermal stress around 100 ^{0}C, diamond can withstand several times that without ill effects. A chip made of diamond could do with a far less robust cooling mechanism and run at unheard-of frequencies without damage. Besides, light-emitting devices made of diamond semiconductors emit radiation of wavelength as short as 235 *nm* (UV region), much shorter that that of the existing devices. For this reason, heated competitions are under way among research laboratories, aiming at the commercialization of electron devices based on diamond semiconductors and applications in diamond power devices in control modules for electric cars and industrial equipment which may lead to considerable energy saving. Given the abundance of this gemstone in Zimbabwe, it would be more prudent that further research in this context be exploited. For applying the diamond semiconductor to electron devices, it is essential to develop technology for synthesizing both ***p-*** and ***n-*** type diamond semiconductors, just like other semiconductors used in electronic devices. Up to now, it has been possible to prepare ***p***-type diamond semiconductor irrespective of crystal orientation by doping with boron. On the contrary, an ***n***-type diamond semiconductor has been regarded very difficult to prepare, with successful synthesis achieved only for (111) surface, and not for (001)[15]. But how can carbon, an insulator and the base material of diamond, become a semiconductor? Research over the years has shown that diamond, when doped with boron, becomes a semiconductor similar to ***p***-type silicon. What has eluded fabricators, though, is a way to make an ***n***-type semiconductor with diamond. Both ***n***-type and ***p***-type semiconductors are necessary to form a transistor. Recent breakthroughs have allowed researchers to reverse the charge of the boron-doped diamond, making an ***n***-type semiconductor.

Meanwhile, diamond does not come cheap for non-diamond mining countries, complemented by hoarding by worldwide diamond conglomerates, like the *De Beers,* making it far too expensive. However, a small Florida-based company called *Gemesis,* is causing a global shake-up in the diamond market, having recently announced a process that can produce large, gem-quality diamonds for as little as US$5 using heat and pressure. This stair can sent shivers to diamond mining countries like Zimbabwe, thereby affecting global prices of rough diamonds, hence the emphasis we make here and elsewhere in the paper for total diamond value addition.

Nanotechnology cancer treatment with diamonds

Researchers from the *Renssalaer Polytechnic Institute* and elsewhere have developed a technique for making magnetic diamond particles of only 4-5 nanometers across. The tiny diamond magnets could find use in fields ranging from medicine to information technology. It is envisaged that, magnetic nano-carbons could make promising structures for high-density memory devices and in quantum computers. And because carbon materials are generally compatible with living tissue, these nanostructures could be useful in medical applications such as magnetic resonance imaging (MRI) and the targeted delivery of drugs to specific parts of the body. Due to its excellent biocompatibility, diamond has been called the Biomaterial of the 21st Century and medical diamond coatings are already heavily researched for implants and prostheses. Nanoscale diamond is also being discussed as a promising cellular biomarker , as a non-toxic alternative to heavy metal quantum dots, and also that nanotechnology diamond ice coatings could improve knee prostheses and solar cells[45,49]. It has been established and demonstrated that a nano-diamond-embedded device could also be used to deliver chemotherapy drugs locally to sites where cancerous tumors have been surgically removed. These nano-diamonds serve as versatile platforms that can be embedded within polymer-based microfilm devices. The nano-diamonds are complexed with a chemotherapeutic, and subsequently enabled to sustain a slow release of the drug for a minimum of one month, with a significant amount of drug in reserve. This opens up the potential for highly localized drug release (especially for the high prevalence of HIV and AIDS (at 14%) in Zimbabwe) as a complementary and potent form of treatment with systemic injection towards the reduction of continuous dosing, and as such, attenuation of the often powerful side effects of chemotherapy.

Diamond coated tools

Structural modification of service properties of material components are enhanced by depositing adherent metallic coatings of micro- and/or nano- dimensions on the surface of the material[1]. The deposition may either be to improve aesthetics, engineering properties or to increase the dimensions of worn or undersized articles. The techniques for achieving any one of these are numerous. Examples are sputtering, chemical vapour deposition, galvanizing, sherardizing, electroless forming, electroplating, etc. Each of these techniques has its specific areas of influence, however, electroplating seems to have a wider appeal than any other member of the coating techniques family[10]. Electroplating ensures the deposition of adherent metallic coatings to change the properties, dimensions of the surface, improve the appearance, hardness or resistance to corrosion.

On the other hand, diamond films have excellent mechanical and tribological properties, such as high hardness and elastic modulus, good wear resistance, low friction coefficient and thermal conductivity, which make them the best candidates for wear resistant applications and for cutting non-ferrous materials such as aluminium and copper alloys and difficult-to-cut materials. Since diamond coated cemented carbide tools have been used widely in the manufacture field, while the deposition technology has been always a key problem, which retards its industrialization. The present researchers mainly focus on the acetonic concentration, the reactive pressure and the temperature of substrate and the bias power. However, the characteristics of diamond coated tools were investigated in a bias-enhanced HFCVD system against uncoated ones[15]. In this investigation the cutting performance of the diamond coated tools was verified by cutting particles reinforced aluminium base composite material with 15 vol.% Sias compared to the uncoated. The quality of diamond film was analyzed by means of Scanning Electron Microscopy (SEM), Raman Spectroscopy and X-Ray diffraction, whilst the relative intensity ratio of (111) facet and (220) facet in the film tested by XRD was obtained at one third. Hence, it was found out that the cutting performance of diamond coated tools was significantly improved, whilst its lifespan was enlongated.

Recommendations

There is great need for Zimbabwe to develop a sound gemological knowledge base through research for diamond beneficiation technologies and opportunities.

Basing on activities taking place elsewhere, Zimbabwe must also establish a national standard regulatory authority for diamond products evaluation, development and certification. This authority will serve as a watchdog for starving off the onslaught of secondary diamond markets, prevent the inherent product misidentification that will follow,produce an inscription technology to 'invisibly' mark the table facet of all Zimbabwean processed and polished diamonds. This mark should only be visible via a point-of-saleelectronic viewer and should come with a certificate of authenticity, whose security features will constitute more complex watermarking to prevent copycats or falsifications.

A gemological laboratory for Zimbabwe must be put in place to deal with:

a) Identification and distinction of natural stones from synthetic stones.

b) Quantification of the hue, tone and saturation of all coloured gem-stones.

c) Grading of diamonds using specified criteria.

d) Use of state of the art technologies in testing for subtle and hard to recognize enhancements such as *HPHT*.

A diamond bourse for Zimbabwe must be established. The world's largest diamond tradingcentre is located in Antwerp, Belgium, but given the fact that Zimbabwe is poised to contribute close to a third of the world's diamond supply network, then it would be in Zimbabwe's interest to control and regulate one. Other diamond bourses are found in Israel, Hong Kong, London, Moscow and Shanghai.

CONCLUSIONS

The grading of a diamond cut tends to be very difficult using unautomated equipment, hence the uncompetitive price ratio per carat. As a result, some evaluators tend not to show in their certificates the important measurements that influence a cut and will not provide a subjective ranking of how good the cut was. At most, several countries have developed diamond cut classification standards; e.g.

- The AGA standards, developed by David Atlas in the 1990s, which may be the strictest at the upper range of quality.
- The HCA which changed several times between 2001 and 2004. As of 2004, an HCA score below 2 represented an excellent cut. The HCA distinguishes between brilliant, Tolkowsky, and fiery cuts.
- The AGS standards changed in 2005 to penalize stones with "cheated" girdles according to Tolkowsky's model and Octonus' ray tracing results.. The grading is from ***0*** to ***10***.
- The GIA began grading cut on every grading report for round brilliant beginning 01-01-2006 based on their comprehensive study of 20,000 proportions with 70,000 observations of 2,000 diamonds. The single descriptive words they used are: *Excellent, Very Good, Good, Fair, and Poor.*

Meanwhile, the distance from the viewer's eye to the diamond is also very important. The 2005 AGS cut standards are based on a distance of 25*cm*, whilst the 2004 HCA cut standards are based on 40*cm*.

- Various labs around the world are using ImaGem's VeriGem device to measure Light Behaviour. DGLA in the USA and Mumbai, India, PCGL in the USA and EGL-USA are both offering versions of this grading in 2008. DGLA has graded thousands of diamonds with this promising direct assessment technology.
- "Brilliancesope" by Gemex is another assessment light behavior technology in use by many US and now foreign retailers and diamond cutters.

Hence, based on these factors, as well as other observations and assertions made elsewhere in the paper, it is necessary that Zimbabwe as a promising giant in diamond mining and processing must endeavour to invest heavily in the scientific and technological research and development of this sector.

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Energy management matrix assessment as a tool for improving organisational energy performance

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ABSTRACT

Managing energy improves the competitiveness of organisations. Energy management matrix assessment for a number of industrial and commercial sector organisations was undertaken to identify priorities attached to six crucial energy management issues. Data collection methods included conducting energy audits and the use of questionnaires. Each key element of the matrix has five ranking levels from 0 to 4. It was observed that organisations have unbalanced matrices. 95% of organisations have an average score of level 1 while a few had an average score of level 3. Formal energy policies are non existent, and some basic energy management activities are done informally. The study revealed that there is no extensive marketing within and outside the organisations, and little account of energy efficiency is considered during investment. The research showed that use of the matrix can help organisations to identify necessary resources required and create a conducive environment for improved energy performance.

Keywords: energy benchmark, efficiency, matrix, policy, score cards

INTRODUCTION

Energy and sustainable development

Energy is a fundamental ingredient for fuelling economic growth. For sustainable socio-economic development energy must be available at all times in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the environment. The environmental protection component calls for extensive investment in energy efficiency, increasing the share of renewables in the energy supply mix and investment in new technologies such as carbon capture and storage (CCS) according to 550 and 450 climate policy scenarios shown in figure 1. Energy efficiency has the greatest impact on sustainable development in the short to medium terms while renewable energy in the long term.

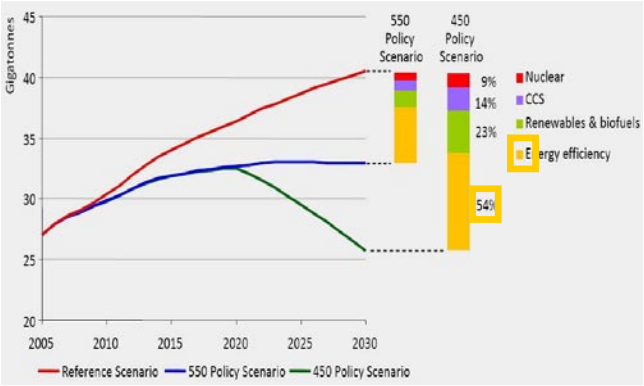

Figure 1: Reduction in energy-related CO_2 emission in the climate policy scenarios (1)

Impacts of energy shortage on companies

In Zimbabwe there is a net deficit in the supply of electricity from internal hydro and coal fired power plants. Power imports are not able to supply the deficit in power due to a number of factors such as industrial growth in the countries which supply electricity and our inability to timely pay for the import bills. The failure by Zimbabwe Electricity Transmission and Distribution Company (ZETDC) to timely pay for imports is due to the fact that it is owed millions of dollars by electricity consumers. Demand Side Management (DSM) initiatives by ZETDC which include reviving and extending the ripple control system on domestic electric geysers in major cities and towns, and fixture relamping roll-out programme, i.e. replacing incandescent bulbs with energy savers are moving at a very slow pace. Power cuts and load shedding are persisting, although at a decreasing rate, leading to loss of industrial production time, resulting in reduced capacity utilisation. Failure to meet production targets and orders by some industries leads to loss of revenue and possibly markets. Due to power outages/load shedding, some industries have been forced to resort to alternative but more expensive sources of power such as diesel powered electricity generators. The high operational and maintenance costs incurred by these gensets lead to increased energy cost intensities. As a result, the final product prices become uncompetitive for local markets in light of stiff competition from imports, and the products are further uncompetitive for export.

Industrial Energy Management in Zimbabwe

Energy savings and productivity are closely linked, i.e. improvements on one side result in benefits on the other. Effective energy management programs therefore improve business opportunities for companies. Energy management is not new to Zimbabwe. In 2001 the Scientific and Industrial

Research and Development Centre (SIRDC) hosted the SADC Industry Energy Management Project (SIEMP) which was sponsored by Canadian International Development Association (CIDA). The program built capacity of Southern African countries in energy management. Local energy consultants, including SIRDC, conducted energy efficiency policy studies in 2005 in six sub-sectors; mining, manufacturing, hospitality, public institutions, transport and agriculture. In 2007 the said consortium undertook preliminary energy audits in seven companies affiliated to the Business Council for Sustainable Development Zimbabwe (BCSDZ) namely Sable Chemicals, Rio-Zim, Bindura Nickel Cooperation, Shangani, Circle Cement, Turnall Fibre Cement and ZimAlloys. From 2007 to 2009 they conducted energy audits in 25 SMEs for the energy efficiency policy draft. The BCSDZ is actively holding workshops on raising awareness on energy and environmental issues with some companies presenting their case studies. As a way to encourage industrial consumers to save energy Zimbabwe Electricity Transmission and Distribution Company runs a competition annually awarding the best three energy efficient companies. Energy audits have been carried out in various sectors of the Zimbabwean economy and the potential savings were found to range between 17% and 47% (3). The majority of companies are approaching energy management in an unsystematic fashion, or not at all. They are missing out business opportunities. For many organisations energy, labour and material resources are the top three operating expenses, with energy being the most manageable expense (4). Globally, businesses today are more focused on managing energy than at any other time in recent decades. To compete globally, our industry should increasingly see energy as a strategic business concern. Worldwide industrial energy efficiency is viewed as a forgotten source of energy whose savings can unlock economic growth. For countries such as Zimbabwe, which are facing energy challenges, the energy saved can reduce occurrence and frequency of load shedding and boost industrial capacity utilisation. Deferment of building power plants will enable the funds planned for expansion of power plants to be channelled to other more pressing issues such as providing working capital for industrial development.

Energy Management Matrix

One tool that can be used by organisations to strategically plan for improved energy performance is the energy management matrix. The matrix was developed in the early 1990s as a tool to help companies to assess their strengths and weaknesses in six key areas of energy management which are policy, organisation, motivation, information systems, marketing and investment. It reveals current priorities attached to organisational energy management and empowers organisations to plan energy efficiency activities for maximising the potential impact of their actions.

The matrix has six columns representing the six key elements as shown in Appendix 1. Each element has five levels of performance ranging from level 0 which is the lowest to level 4, the highest or best practice. Moving up the matrix signifies an increasingly mature and formal approach to handling energy management activities and implies increasingly 'good' practice.

OBJECTIVES

The overall objective of the ongoing research is to improve competitiveness of the Zimbabwean industrial sectors through implementation of energy conservation and energy efficiency projects. The energy management matrix was used as a tool to help organisations establish and implement more effective energy management programs. The strengths and weaknesses of the current energy management practices were identified and opportunities for improvement identified.

The secondary objectives of the study included reducing energy intensities, energy cost intensities and hence overall production cost indices, reducing environmental impact of organisational businesses, improving reliability of energy consuming systems leading productivity and quality improvements.

METHODOLOGY

A number of methods were used for gathering energy data for the research. These included sending 15 questionnaires on energy management matrix assessment, conducting energy audits (14 walkthrough and 8 detailed), examination of balanced scorecards and benchmarking energy performance, discussion and interviewing key energy personnel such as energy coordinators/managers, the Safety Health Environmental (and Quality) managers and officers, production managers, boiler superintendents and operators and technicians/artisans (electrical, mechanical and instrumentation).

Walkthrough and detailed energy audits were conducted to establish where and how energy is used in organisations, as well as the potential for energy savings. Energy management initiatives by organisations were also investigated for their effectiveness; what worked perfectly to be used as best practices, challenges and how they can be overcome. Balanced scorecards were reviewed to determine how qualitative and quantitative they were. Energy performance of organisations from the balanced scorecards and those determined from detailed energy audits were compared with historical performance and also benchmarked against national, regional and international best practices.

The energy management matrix is shown in Appendix 1. The questionnaire for energy matrix assessment was prepared by formulating questions on the six key elements of energy management. The questions were also used for in-depth discussions and interviews.

Questions for the energy stakeholders included the following:

Policy and systems

- Does the organisation have formal energy and/or environmental policies and state them?
- Is there active commitment of top management?
- Does the policy commit to providing the resources and information needed to achieve the energy objectives and targets?
- With respect to the organisation's energy use, does the policy commit to complying with legal requirements?
- Is the purchase of energy efficient products and services supported by the policy?
- Is the energy policy documented?
- Is the policy communicated to employees and others working on behalf of the organisation such as on-site contractors and suppliers?
- Is the policy regularly reviewed and updated as needed?

Organisation

- Does the organisation have a dedicated energy team and an energy manager/coordinator?
- Is energy management integrated into the management structure of the organisation?
- Is there delegation of responsibilities?
- Is the energy team aware of its roles and responsibilities?
- Do you have energy targets, goals and action plans?
- Does the organisation hold energy reviews, if so how often?
- What role does top management play?

Energy information system

- What energy sources does the organisation use?
- What energy data does the organisation record?
- How are energy data collected, at what level and how often?
- What methods of tracking energy information?
- Does the organisation benchmark energy performance, if so how?
- Has your company established an energy baseline from which to measure progress?
- What information is reported to top management and what does management do with this information?

Motivation

- How are staff motivated to come up with new ideas for energy improvements?
- Does the company give rewards or recognise staff for good ideas and if so how?
- What role does top management play?

Training and awareness

- Is there training for staff on energy management and conservation? Who is trained, what the training is about and who gives the training?
- Is there awareness raising for staff on energy management and conservation?
- How awareness is raised, what the awareness is about, for which staff and who does the awareness raising.
- Is there marketing of the importance and results of energy and environmental management outside the organisation? To whom, how often, how this is done, does this include energy and greenhouse gas emissions?

Investment

- Does the organisation have a purchasing policy that takes into account the energy implications of your purchasing decisions?
- What criteria are used for the evaluation of any projects?
- What are the minimum criteria that a project (including an energy project) must meet? Have there been projects that were not implemented, and is so why?

The organisational profiles were established by placing marks in each column which best describe the position where the organisation is located with to the six key elements of energy management. The marks are joined by a line to produce the organisational profile. This gives an indication of how balanced energy management is for the organisation. The peaks indicate where organisational effort is most sophisticated and the troughs represent areas which should be improved. The areas with lowest scores are addressed by reviewing energy management to bring the profile into balance. Energy management reviews checks the energy management program for suitability, adequacy and effectiveness. Obstacles that led to poor performance on some key elements of energy management are identified and ways to overcome them are determined. Opportunities for improvement are identified and methods of exploitation are determined. Expected outcomes from the energy review include decisions or actions related to improvement in energy performance such as institution of energy or changes to the energy policy, changes to energy performance indicators, changes to objectives, targets or other elements of the energy management system and allocation of resources. Profiling energy management matrices assists organisations to plan or organise energy management

strategies. Once the profile is balanced, the organisation should aim to then move up the matrices in a balanced way.

RESULTS AND DISCUSSIONS

Energy audits revealed that potential energy and cost savings are inversely proportional to the average score on the matrix. This means that the lower the average score the greater the potential savings resulting from inefficient energy use. Thus poor energy performance is associated with lower average scores. To improve energy performance organisations must improve their average scores towards 4, which is the best practice.

Organisations have unbalanced matrices and they can be divided into two groups according to the average scores on matrix assessment. The majority representing about 95% of organisations had an average score of level 1 (i.e. < 1.5) indicating that there is some commitment to manage energy even though there is no formal energy policy. Awareness of energy efficiency is created informally and monitoring of energy is done to a limited extent. Scores on individual key elements of energy management ranged from 0 to 2 indicating poor coordination of energy management programs. Figure 2 shows the organisational profile of one of the companies in this group. About 5% of the organisations had an average score of 3 (i.e. ≥ 2.5 but < 3.5) indicating that energy is taken more seriously by top management and energy management is integrated into the organisational management structure. There is a comprehensive energy information system and an effective marketing and energy efficiency investment program. However organisations do not benchmark energy performance against regional and international best practices. A typical profile for this group is shown in figure 3.

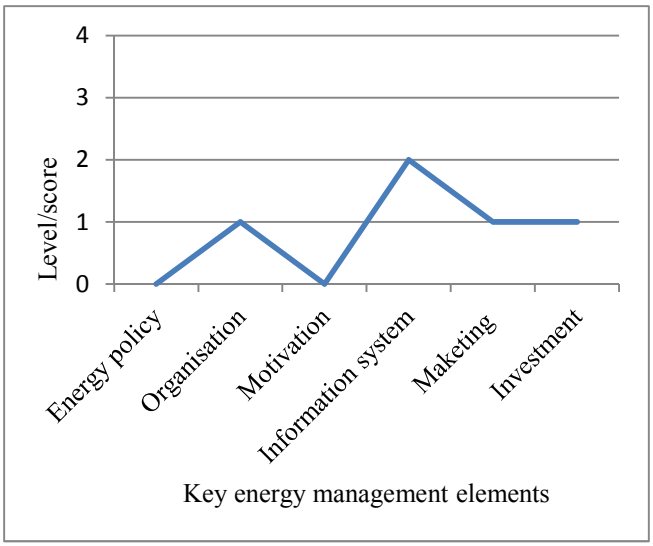

Figure 3: Typical organisational profile for poor energy performing companies

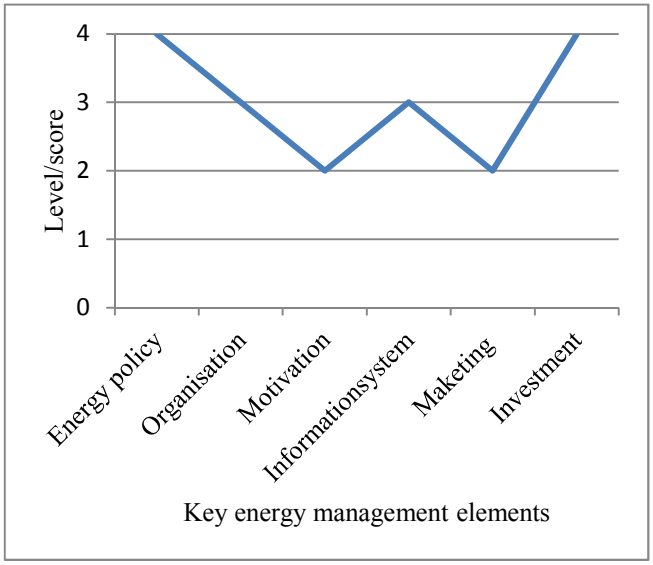

Figure 4: Typical organisational profile for better energy performing companies

Overall energy management information system and marketing had relatively better scores compared to other elements. Most organisations had environmental management systems. They implemented some energy management activities under these systems.

A closer look at organisations with an average score of 1 revealed that:

a. Top management finds production more important than managing energy. As a result there are no energy management programs, energy management is seen as a technical issue and is not integrated into the organisational management structure. There are no energy management coordinators to help organisations achieve their goals by establishing energy performance as a core value. Neither do organisations have dedicated energy teams to execute energy management activities across different departments of the organisation and ensure integration of best practices. Some stated that management is concerned about the investment cost in energy efficiency measures. They consider investments using short payback periods rather than the life cycle costs. Awareness raising to top management is very essential. Unfortunately, top management does not participate in energy workshops, they send middle managers. Therefore awareness raising seminars should be arranged and conducted for top management.

b. Organisations were affected by lack of technical capacity or know-how in the development and implementation of energy efficiency measures. They do not have even minimum

technical knowledge of energy, production processes and equipment required to be able to access energy use, investigate and implement options to improve energy performance. Technical trainings are still required to build the capacity of industries to manage energy. Data capturing by informal energy teams currently at most organisations is limited by absence of energy sub meters. For instance most companies rely on electricity and water metres installed by service providers and utility bills. Very few have sub meters to determine energy and water consumption of energy intensive equipment, sections or departments. With sub metering, inefficient processes, equipment, sections or departments can be easily identified and corrective action taken much earlier to improve energy performance.

c. There is insufficient information and data on end-use energy consumption. Due to lack of information it was difficult to convince top management that improved energy performance can improve business performance of organisations. Top management requires facts and figures reduced to monetary values; how much to invest in energy efficiency, the expected returns and how long it takes to recoup the investment. Without comprehensive energy information, top management will not avail the necessary resources to drive effective energy management programs. The majority of staff are not motivated to save energy as they do not know why they should save energy and how they can save energy. Marketing of energy issues should be conducted within and outside the organisation for improved energy performance and improved reputation with the public resulting in enhanced business opportunities.

d. Some organisations experienced financial limitation in implementing energy efficiency measures. Generally energy efficient equipment is expensive and as a result most organisations opt for cheaper energy inefficient equipment. The liquidity crisis affecting our economy further worsens the situation as it is difficult to obtain loans at viable interest rates for financing energy efficiency projects.

CONCLUSION

Top management commitment expressed in the form of an energy policy is vital for effective energy performance. Proper planning with formal energy policy improves energy performance. This is evidenced by the smaller group of organisations with an average score of 3. These organisations either had energy policies ratified by top management or they are at advanced levels in developing energy policies with the full backing of top management. Top management provided all the resources; financial, systems and functions, human, equipment and external services. The

other five key elements are dependent on policy and planning. Poor energy performance of the majority of organisations also reveals that without active commitment of top management expressed in the form of formal energy policies, implementing energy efficiency projects is an extremely tall order.

Technical solutions alone do not achieve maximum energy and cost savings. Energy management has the greatest impact when an organisation addresses or balances the three dimensions of energy management which are technical, organisation and behavioural.

High scores on the matrix pay off; there is a correlation between their scores on the Energy Management Matrix and the energy savings that they achieve (4). That is, developing the competencies associated with good energy managing companies pays off in real energy savings. The few organisations with an average score of 3 managed their energy and reported improved business performance while the majority with an average score of 1 reported inconsistent business performance, a cycle of losses, marginal profit and break even position.
Standard management systems compliment one another. Organisations with active quality and environmental management systems found it easier to institute and implement energy management programs.

RECOMMENDATIONS

The energy management matrix assessment should be undertaken at planned intervals for continual energy improvement. It is important to involve both senior managers and end users in the processes in assessing the energy matrix and to identify the steps needed to fully implement the energy management elements at organisational facilities (5). Getting as wide a spread of people as possible gives an idea as to how energy management is perceived throughout the organisation. In addition, the companies should initially focus on balancing their matrices; then move up towards the best practice with balanced matrices to fully benefit from energy management programs.

Organisations struggling to manage energy should initially focus on obtaining top management commitment by quantifying potential energy savings in monetary terms. This enables organisations to be availed with necessary resources to manage energy and for continual energy improvement. With full backing of top management they should have formalised energy management systems with specific targets for energy use reduction. This will facilitate most of the energy activities currently carried out informally. Organisations can adopt the ISO 50001 global energy management

system standard which enables an organisation to take a systematic approach towards achieving continual improvement of energy performance, energy efficiency and energy conservation. ISO 50001 integrates energy efficiency into existing industrial management systems for continuous improvement and is compatible with ISO 9001 and ISO 14001. The standard helps in energy planning, implementation and operation, monitoring, measurement and analysis, documentation and progress review (6).

Improving the organisational energy marketing strategy is necessary. Marketing is about needs and benefits, i.e. why an organization should implement energy management activities and the benefits realized or to be realized by the organisation, community and to individuals. Promoting energy management involves raising awareness of the importance of energy efficiency to cost and environmental conservation, training to improve organizational capacity to manage energy and publicizing achievements in energy management outside the organization to improve reputation with customers.

Staff should be motivated to save energy and to come up with energy saving options. Managing energy is no longer a technical issue alone. Being successful in saving energy is thus a question of changing people's behaviour, motivating them to behave differently.

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APPENDICES

Appendix 1: Energy Management Matrix

Level	Energy policy	Organisation	Motivation	Information system	Marketing	Investment
4	Formal policy with active commitment	Energy Management (EM) integrated into management structure	Formal and informal channels of communication exploited by energy team	Comprehensive system sets targets, monitors consumption, identifies faults quantify savings and provides budget tracking	Marketing Energy Efficiency (EE) value and performance both within and outside	Positive discrimination in favour of green schemes with detailed investment appraisal
3	Formal policy but no active commitment	Energy manager accountable to energy committee	Energy committee used as main channel together with direct contact with major users	Monitoring and Targeting reports for individual premises	Awareness and regular publicity campaigns	Same payback criteria employed for all other investment
2	Un adopted energy policy	Ad-hoc reporting by energy manager	Contact with major users through ad hoc committee	Energy unit has an ad hoc involvement in budget setting	Ad hoc staff awareness and training	Investment using short term payback period criteria only
1	Unwritten set of guidelines	EM part time responsibility of someone with limited authority	Informal contacts between engineer and a few users	Cost reporting based on invoice data	Informal contacts to promote EE	Only low cost measures taken

Towards An Operational Geographical Information System For Monitoring Vector Species' Habitat Change In A Changing Climate

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ABSTRACT

Global environmental change is taking place at different scales in space and in time. Models have been developed and applied to predict the future climate at every point on earth. This paper investigates the consequences climate has on vector borne disease distribution. We have applied spatially defined models that can make projections of vector species habitat change in space and time. Our results show that we can use models based on geo referenced field observation data and environmental data including Remotely Sensed environmental data to effectively map fauna species' habitat. The models we have used to model present species distribution have performed better than random (AUC 0.9, $p<0.05$). Thus, when applied to future climate they can predict species habitat change in space and in time as the climate changes. Therefore, based on the model's predictive power and ability to project future distribution we develop a basis for an operational spatially defined monitoring system that can be used for monitoring habitats of vectors such as tsetse flies that spread diseases in humans and livestock under changing climate scenarios.

Keywords: **Maximum entropy, *Glossina morsitans, Glossina pallidipes*, Area under the curve (AUC), jackknife, Climate change.**

INTRODUCTION

The tsetse fly is the vector that transmits trypanosomes that cause sleeping sickness in people and trypanosomiasis in livestock such as cattle, sheep and goats (Kitron et al., 1996 (1); Reid et al., 2000(2); Terblanche et al., 2008(3)). Presence of trypanosomes may slow or prevent expansion of agriculture and rural development because farmers do not have healthy draft oxen (Cecchi et al., 2008(4); Kitron et al., 1996(1); Reid et al., 2000(2); Terblanche et al., 2008(3)). Control of trypanosome parasites depends largely on the successful management of tsetse populations (Kitron et al., 1996(1)). Spatial heterogeneity in environmental conditions results in local differences among fly populations (Kitron et al., 1996(1)).

Until the mid-1970s, the Zambezi valley was sparsely populated due to prevalence of tsetse flies and tsetse-related diseases like sleeping sickness. Eradication of tsetse flies in the early 1980s resulted in rapid immigration and settlement by farmers (Murwira and Skidmore, 2005(5), Murwira et al., 2011(6)). In Zimbabwe in general tsetse flies have been eradicated from an area of 48,000 km^2 between 1981 and 1989 through pesticide control, involving ground spraying, aerial spraying, cattle dipping and artificial bait techniques (Shereni, 1990(7)).

However, to maintain the low levels of tsetse in the Zambezi valley, the spatial distribution of tsetse flies has to be constantly monitored by elaborate trap counts and spraying campaigns have to target areas where the tsetse fly remains prevalent. Earth Observation and Geo-information Sciences are adding the crucial component of spatial extrapolation from ground observations. Remote sensing (RS) and Geographic Information Systems (GIS) are increasingly applied to studies of vector-borne diseases for data management and analysis (Bergquist, 2001(8); Brownstein et al., 2002(9); Cecchi et al., 2008(4); Hales et al., 2002 (10); Kitron et al., 1996 (1); Kulkarni et al.,2010 (11); Peterson et al., 2005 (12); Rácz et al., 2006 (13); Reid et al., 2000 (2)) as species distribution models facilitate interventions to eliminate vector-borne diseases (Brownstein et al. 2002 (9), Kulkarni et al. 2010 (11)) through identifying reservoirs/sources for disease (Cecchi et al., 2008(4); Drake et al. 2000 (14)). GIS and RS based species distribution models can be used to estimate risk of infection, increase the efficiency of protective measures and help understand the factors that influence the geographic extent of disease (Rácz et al., 2006 (13)) as well as understand the spatial epidemiology of human, animal and zoonotic diseases that are vector-borne, including trypanosomes and malaria (Cecchi et al., 2008 (4)). Therefore, spatial distribution models of vectors of disease make it possible to effectively implement eradication programmes.

The detail and accuracy of most available maps for tsetse distribution are still not adequate for the challenges posed by the planning and implementation of field projects on a large scale (Cecchi et al., 2008(4)). Therefore there is need for site specific spatial models to show the spatial distribution of tsetse flies. In addition, tsetse-born trypanosomiasis is an under-investigated vector-borne disease, especially with regards to the limited number of climate change based predictions (Terblanche et al., 2008 (3)).

The prevalence of Glossina spp and the trypanosomes it transmits has been a major problem in North-western Zimbabwe. The government of Zimbabwe through its Tsetse Control Division is implementing extensive research in order to understand the habitat of the vectors and in order to effectively assess the prevalence of the vectors (Pender et al., 1997 (15); Shereni, 1990 (7)). A continuous monitoring programme is implemented to monitor the changes in the spatial distribution of vectors. This programme employs field trap counts. This paper describes how Remote Sensing and a Geographic Information System (GIS) were used in conjunction with field trap counts to develop predictive *Glossina* spp habitat models factoring in various climate change scenarios.

Recently developed machine-learning algorithms can accurately estimate species distribution (Brownstein et al., 2002 (9)) and they are handy where presence only data is available. The maximum entropy (MAXENT) technique by Phillips et al. 2006 (16) was used for the *Glossina* habitat models. MAXENT is considered relatively reliable (Kulkarni et al., 2010 (11))

The aim of this study was to determine the relationship between tsetse flies distribution and environmental factors such as remotely sensed altitude as well as temperature and rainfall variables and then apply the relationship found to projected climate change scenarios.

MATERIALS AND METHODS

The study area is the Matusadona Project area that includes the Matusadona National Park near Lake Kariba. The Matusadona Project area covers about 7535.37km^2. The area has undulating topography with the average elevation of between 700 and 800 m above sea level. It is characterised by a single wet season (November to March) with a mean annual rainfall of 680–700 mm, as well as a long dry season (April to October). The vegetation consists of Miombo, Mopane, Faidherbia and Miombo-Mopane woodlands as well as Setaria grasslands (Matawa et al., 2012 (17); Murwira and Skidmore, 2005 (5)).

Georeferenced tsetse observation data was collected by the Tsetse Control Division of the Veterinary Services Department of the Ministry of Agriculture, Mechanisation and Irrigation Development of Zimbabwe. The data was collected at different times spanning the wet and dry season from September 2010 to June 2011. The study area was divided into grids and within each grid optimal sampling points were marked on a map. At predetermined times from setting the traps the trapped number of flies were recorded and includes *Glossina morsitans*, and *Glossina pallidipes* as well as other biting flies like tabanids.

The elevation of the study area was derived from a readily available Shuttle Radar Terrain Mission (SRTM) digital elevation model (DEM) (http://srtm.csi.cgiar.org/ accessed 2009). Other variables such as current long term rainfall and temperature as well as projected temperature and rainfall variable for 2020s, 2050s and 2080s were mapped for the study area using Worldclim data (Hijmans et al., 2005 (18) and www.worldclim.org). The data on future climate scenarios was based on data from the Canadian Centre for Climate Modelling and Analysis (CCCMA) available in Worldclim. Two emission scenarios were used, where the level A2a emission assumed regionally oriented economic development with temperature increases ranging from 2.0^0C to 5.4^0C and the level B2a emission assumed local environmental sustainability with temperature ranging from 1.4^0C to 3.8^0C. We generated bioclimatic variables using DIVAGIS for use in the habitat model.

Error! Not a valid bookmark self-reference. shows the codes for variables used in the habitat models.

Table 2: Variables used in the model

Code	Description
BIO1	mean annual temperature
BIO2	mean diurnal range (mean of monthly (maximum temperature - minimum temperature))
BIO3	Isothermality (BIO2/BIO7) (*100)
BIO7	temperature annual range (Maximum temperature of the warmest month (BIO5)- minimum temperature of the coldest month (BIO6)
BIO8	mean temperature of wettest quarter
BIO9	mean temperature of driest quarter
BIO10	mean temperature of warmest quarter
BIO11	mean temperature of coldest quarter
BIO12	annual precipitation
BIO13	precipitation of wettest month
BIO15	precipitation seasonality (Coefficient of Variation)
BIO16	precipitation of wettest quarter
BIO17	precipitation of driest quarter
BIO18	precipitation of warmest quarter
BIO19	precipitation of coldest quarter

The field data was collected across different times in the season and could not be used in linear regression as that may misrepresent the behaviour of the flies throughout the season. Therefore, we used the Maximum Entropy Technique (MAXENT) (Phillips et al., 2006 (16); Phillips and Dudik, 2004 (19)), a presence-only modelling technique, to model the *Glossina* spp species. The data of all traps where tsetse flies were trapped was used as presence observations irrespective of the difference in time of observation. MAXENT is a modelling technique which uses presence-only data to measure entropy, a measure of "how much 'choice' is involved in the selection of an event" (Phillips et al., 2006 (16)).

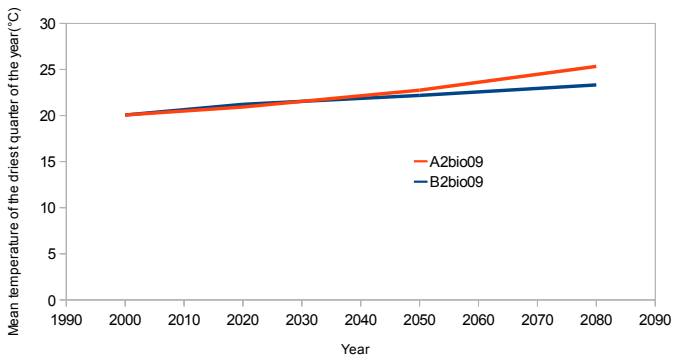
The freely available MAXENT software (http://www.cs.princeton.edu/~schapire/MAXENT/ Accessed 2011, version 3.3.2), which generates an estimate of probability of presence of the species based on several spatially defined variables was used (Brito et al., 2011 (20); Matawa et al., 2012 (17); Phillips et al., 2006 (16); Phillips and Dudik 2004 (19)).

For training the model we used only 70% of the observation records while the other 30% of the records were used to test the model performance (Matawa et al., 2012 (17)). These test data were randomly selected and were not used in the training of the model. We evaluated the model using the receiver operating characteristic Curve (ROC), which is a graphical plot of the true positive rate (or sensitivity or 1-Omission rate) versus the fraction of the total study area predicted present (or 1 − specificity) for the binary classifier system as its discrimination threshold is varied (Phillips et al., 2006 (16); Phillips and Dudik 2004 (19)). The ROC is used to generate a summary statistic called the area under the ROC curve, or "AUC" whereby it is less than or equal to 0.5 the prediction of the model is random while AUC greater than 0.5 means the prediction is better than random (Matawa et al., 2012 (17); Phillips et al., 2006 (16); Phillips and Dudik 2004 (19)).

RESULTS

Analysis of Environmental Variables

The projected climate data for the study area shows a general increase in temperature and a general decrease in rainfall (Figure 4a and b). Isothermality (The mean diurnal range divided by the Annual Temperature Range) will increase (Figure 4c).



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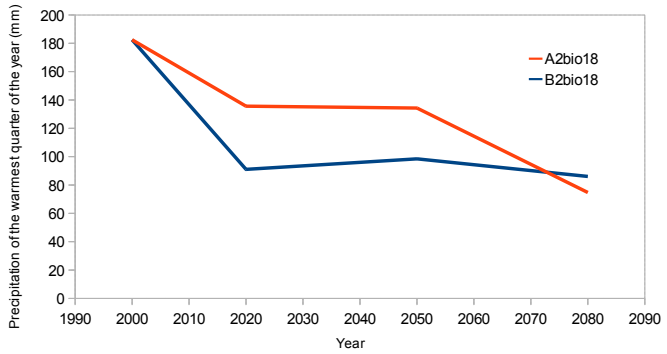

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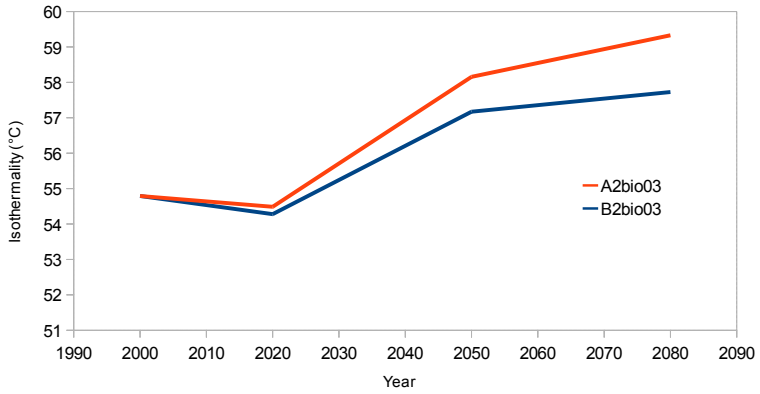
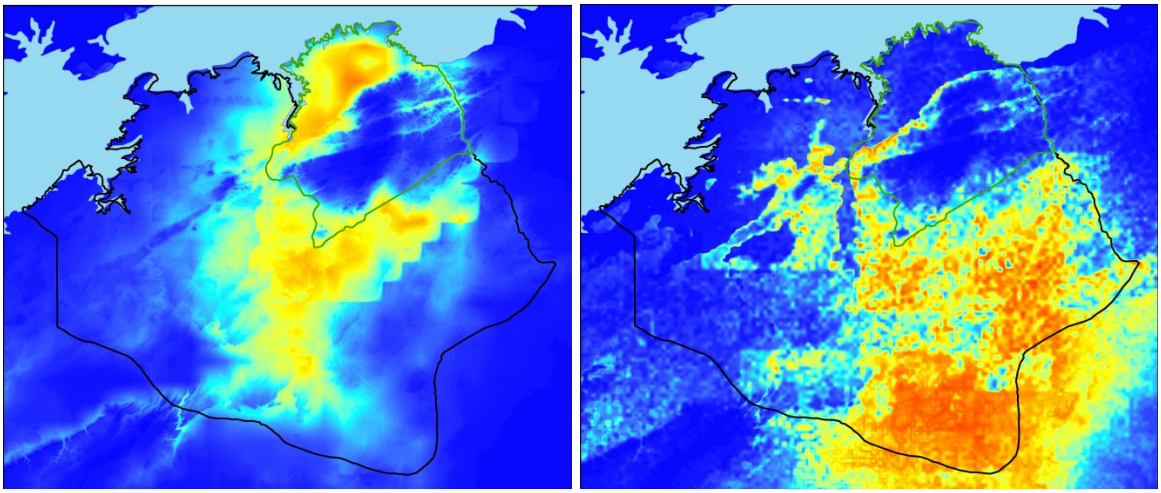


c.

Figure 4: Graphs showing current climate and projected climate change trends for 3 select variables (a) mean temperature of driest quarter (b) precipitation of warmest quarter (c) Isothermality.

The spatial distribution ofGlossina morsitans

Figure 5shows the probability distribution of *Glossina morsitans* based on presence data and environmental factors. Blue shows low probability of occurrence whilst red shows high probability of occurrence. Figures 2b, b and c show the probability distribution of *G. morsitans* based on CCCMA level A2a emission 2020s, 2050s and 2080s projected climate data (www.worldclim.org) respectively. Figure 6a, b and c show the probability distribution of *G. morsitans* based on level B2a emission 2020s, 2050s and 2080s projected climate data (www.worldclim.org) respectively. The relative importance of environmental variables used to model the spatial distribution of *G. morsitans* is illustrated in Figure 7. The results of the jackknife of variable importance (Figure 4) show that precipitation of the warmest quarter of the year (bio18), Isothermality (bio3) and mean temperature of the driest quarter of the year (bio9) contributed the most in defining the outcome of the model as compared to all other variables. Figure 8 shows the receiver operator characteristic curve (AUC) for training and test data that was used to measure model accuracy. Figure 8 shows that the model performed significantly better than random ($p<0.005$) and the AUC for test data is 0.910.



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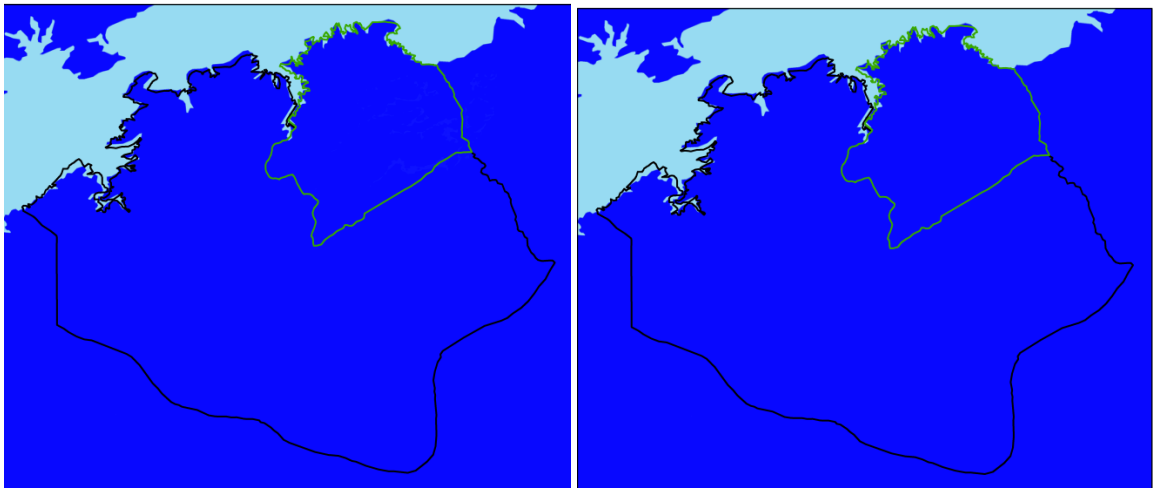

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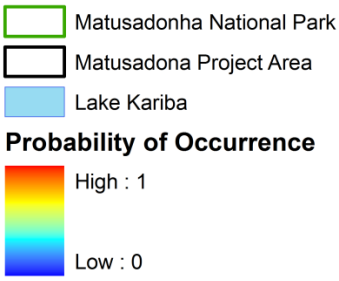
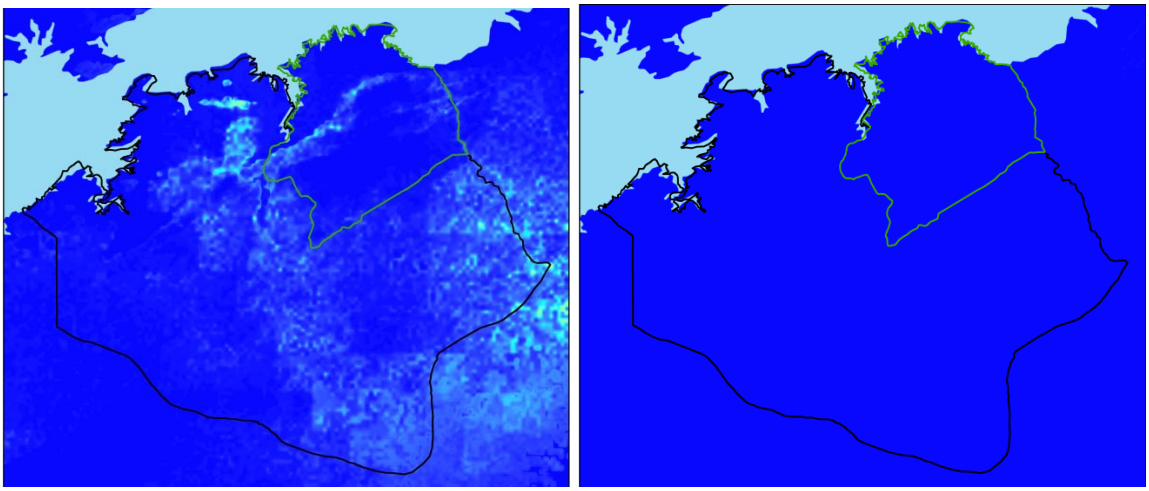


Figure 5: Progressive change in tsetse (*G. morsitans*) probability distribution (a) based on current climate (b) based on CCCMA level A2a 2020s (c) 2050s (d) 2080s climate scenarios.



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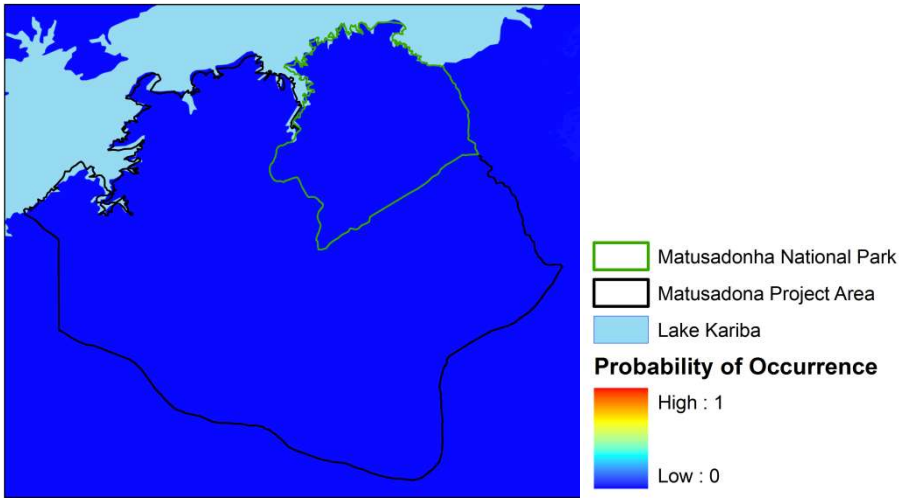

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Figure 6: Progressive change in tsetse (*G. morsitans*) probability distribution based on CCCMA level B2a climate scenarios (a) for the 2020s (b) 2050s and (c) 2080s.

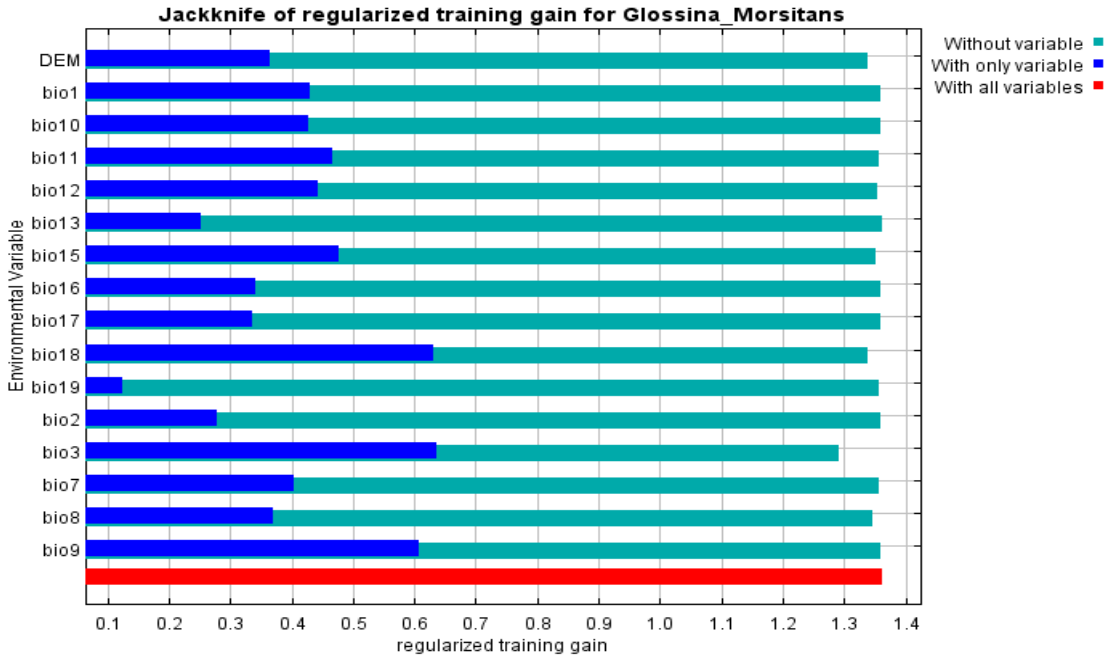

Figure 7: Jackknife of variable importance in modelling the spatial distribution of *Glossina Morsitans*

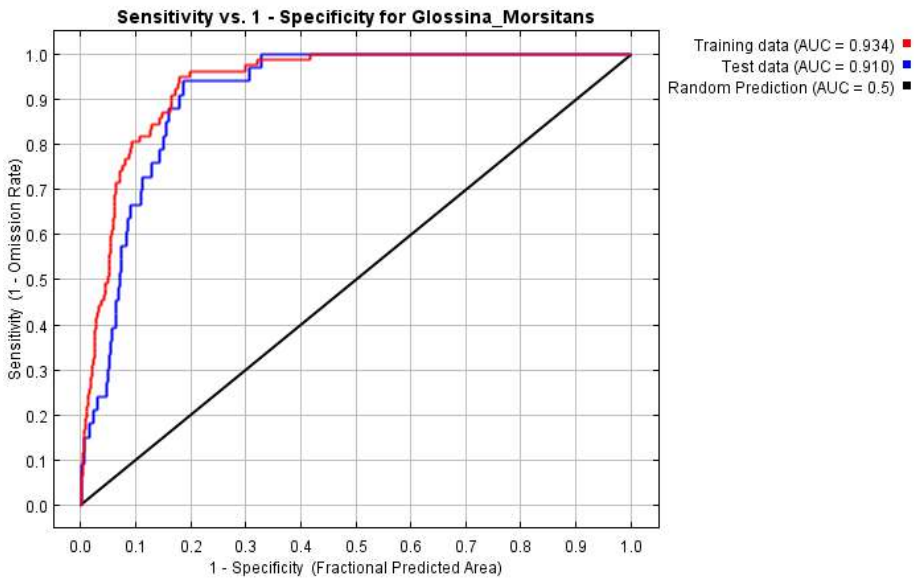

Figure 8: Shows the receiver operator characteristic curve (AUC) for training and test data that was used to measure model accuracy.

The spatial distribution ofGlossina pallidipes

Figure 9a shows the probability distribution of *Glossina pallidipes* based on presence data and environmental factors. Figure 9b, c and d show the probability distribution of *G. pallidipes* for level A2a emission for 2020s, 2050s and 2080s climate scenarios respectively. Figure 10 a, b and c show

the probability distribution of *G. pallidipes* for level B2a emission for 2020s, 2050s and 2080s climate scenarios respectively. The relative importance of environmental variables used to model the spatial distribution of *G. pallidipes* is illustrated in Figure 11. The results of the jackknife of variable importance show that precipitation of the warmest quarter of the year (bio18), mean temperature of the coldest quarter of the year (bio11), mean temperature of the driest quarter of the year (bio9), mean temperature of the wettest quarter of the year (bio8), mean annual temperature (bio1) and elevation (DEM) contributed the most in defining the outcome of the model as compared to all other variables. The receiver operator characteristic curve (AUC) for training and test data show that the model performed significantly better than random ($p<0.005$) and the AUC for test data is 0.897 (Figure 12).

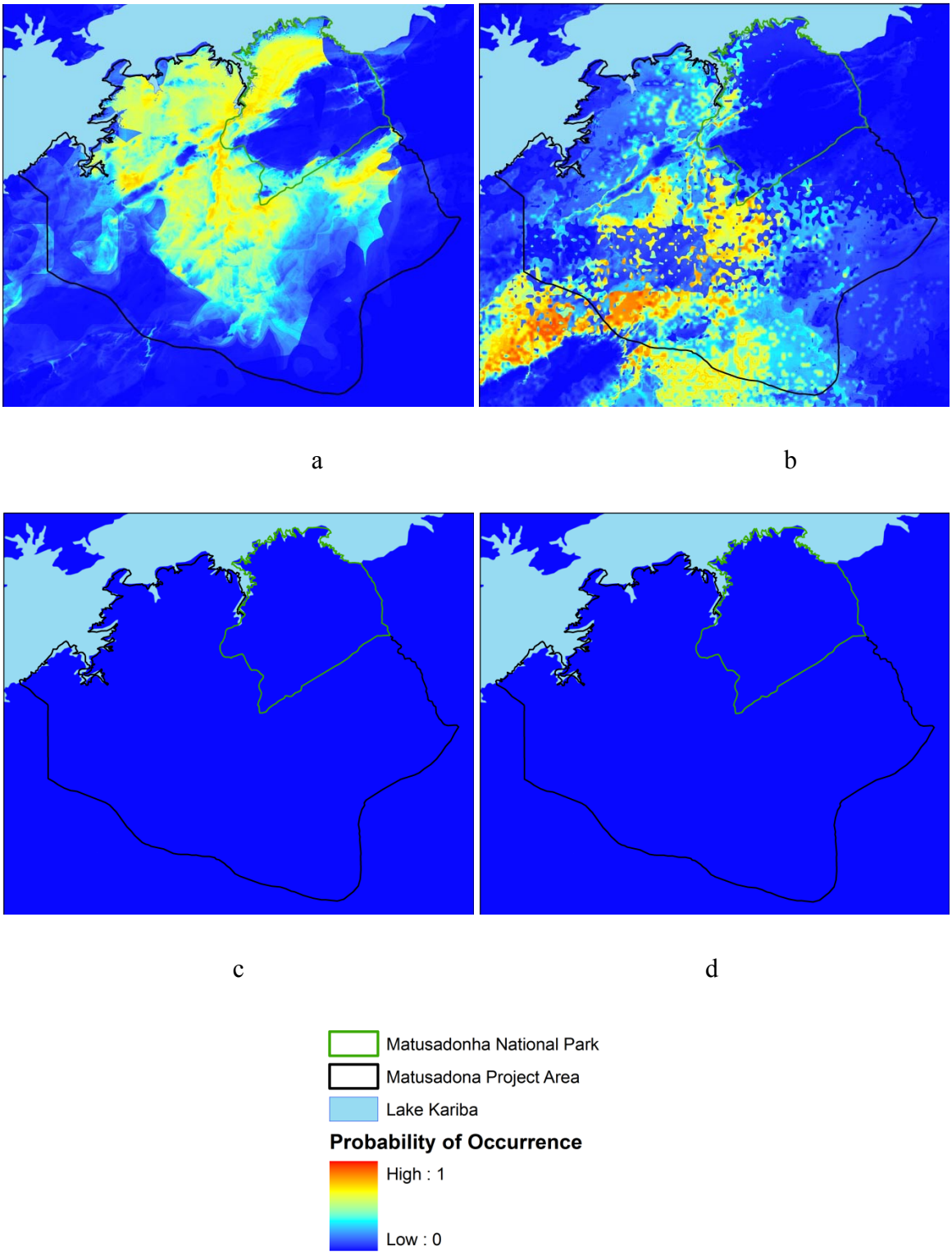

Figure 9: Progressive change in tsetse (*G. pallidipes*) probability of occurrence: (a) distribution based on current climate (b) based on CCCMA level A2a 2020s (c) 2050s and (d) 2080s climate scenarios.

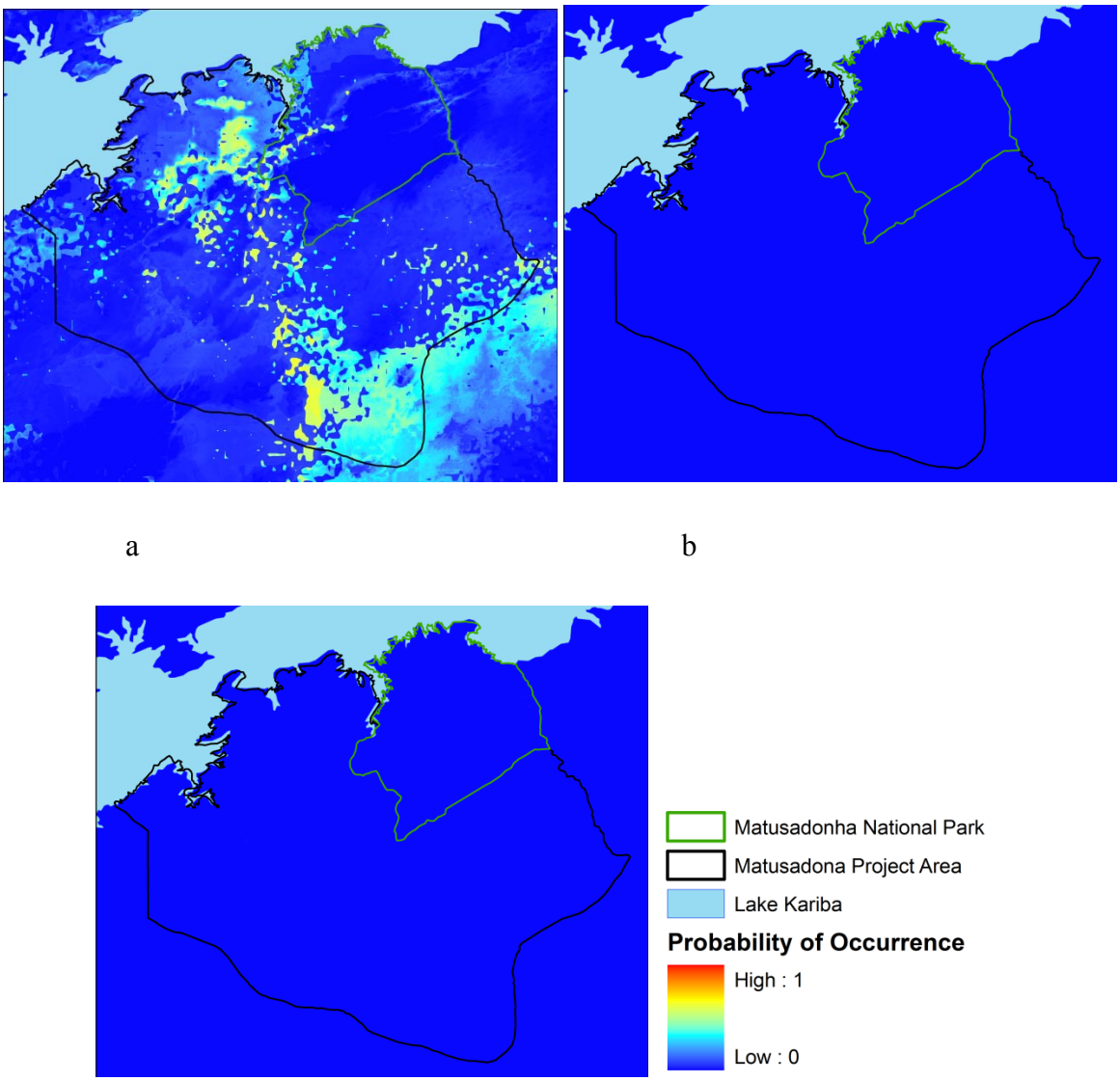

Figure 10: Progressive change in tsetse (*G. Pallidipes*) probability of occurrence based on CCCMA level B2a (a) 2020s (b) 2050s and (c) 2080s climate scenarios.

Figure 11: Jackknife of variable importance in modelling the spatial distribution of Glossina Pallidipes a

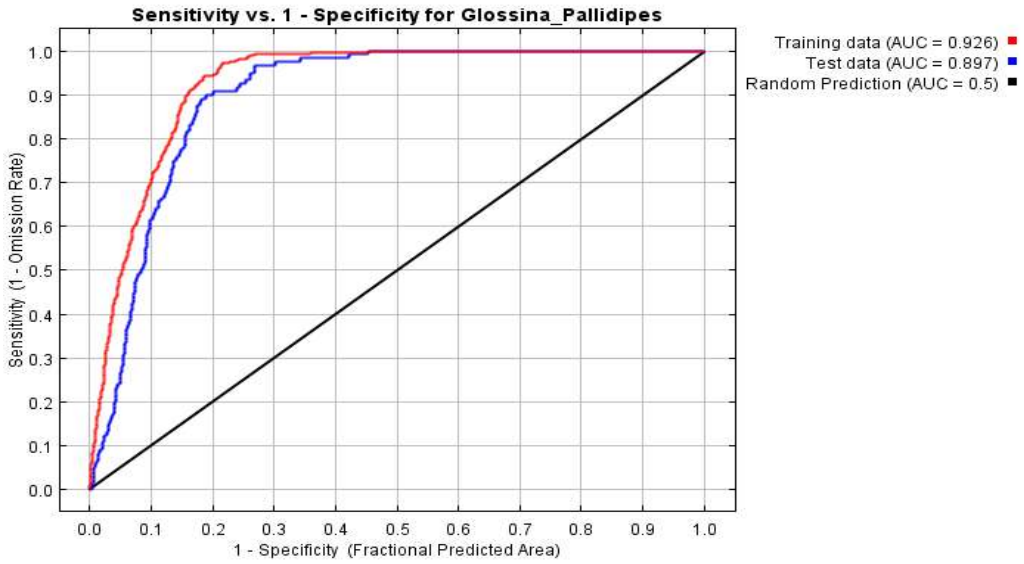

Figure 12: The receiver operator characteristic curve (AUC) for training and test data that was used to measure model accuracy.

DISCUSSION

The spatial distribution ofGlossina morsitans

The present habitat distribution models (Figure 2 and 3) of *G. morsitans* are accurate as evidenced by the high AUC number when using the 30% test sample for tsetse observed in the field. AUC values closer to 1 show that the classifier was able to distinguish between suitable and unsuitable tsetse fly habitat and the model performed significantly better than random (Phillips et al., 2006). And the spatial distribution is dependent on precipitation of the warmest quarter of the year, Isothermality, mean temperature of the driest quarter of the year. Based on the accuracy of the present species distribution model, we applied the same model criteria to model the *G. morsitans* habitat for the future climate change scenarios.

The model shows a progressive decline in the probabilities of tsetse occurrence in the study area. Especially for 2050s and 2080s, the projected probability of finding tsetse in the Matusadona project area is close to zero. Similar to results based on level A2a emission scenario, the results based on level B2a emission scenario show a progressive decline of the tsetse habitat as well as a north-easterly migration trend.

The results for *G. morsitans* are consistent with the work by Brownstein et al., 2002; Cecchi et al., 2008 (4) and Kitron et al., 1996 (1) showed that tsetse habitat is influenced by climate variables. Kitron et al. (1996 (1)) observed that fly abundance is positively related to temperature and humidity. Our results show the influence that altitude has on the tsetse distribution, as low probabilities were predicted for the mountain ranges such as Matusadona range and the Mapongola hills whilst high probabilities were predicted for low lying areas. Altitude influences micro-climate especially temperature where high temperatures are associated with low lying areas. Precipitation of the warmest quarter that creates humid conditions had the most useful information not contained in other variables and was the major determinant of the habitat of *G. morsitans*. Isothermality was the second most important variable.

In addition, the decrease in tsetse habitat due to climate change and shift of tsetse fly habitats is consistent with the results of Hulme (1996 (21) and Terblanche et al. (2008) (3) whose studies suggest a reduction in suitable habitat for *G. morsitans* and hence a contraction of its geographic range under various future climate change scenarios.

The spatial distribution ofGlossina pallidipes

The results shows that there will be a decrease in size and quality of *G. pallidipes* habitat with change in climate as it becomes hotter and drier in relation to current climate. The AUC is greater than 0.5 thereby showing that the classifier was able to distinguish between suitable and unsuitable *G. pallidipes* habitat.

The results for *G. pallidipes* are consistent with the work of Terblanche et al. (2008) (3) who suggested that these species are strongly influenced by temperature and moisture availability in all life stages and there is a critical minimum and a critical maximum temperature using experimental methods. Temperature variables played an important role in influencing the probability distribution of *G. pallidipes* as compared to other variables (Figure 11) especially mean temperature. Precipitation and elevation also played an important role. The spatial models (Figure 9 and Figure 10) clearly show the influence of elevation as evidenced by low probabilities over the Matusadona range and the Mapongola hills. Areas below 1100m are climatically suitable for tsetse (Pender et al., 1997(15)). Vegetation, climate and availability of hosts are key elements that determine the suitable habitat of tsetse (Cecchi et al., 2008(4)). Thus climate influences tsetse fly habitat.

In addition, the fact that climate change may result in decline or loss of tsetse fly habitats is supported by the findings of Terblanche et al. (2008) (4) who alludes that there may be reduced geographic distribution under future climate warming scenarios.

CONCLUSIONS

This study concludes that the present habitat of *Glossina* species can be modelled accurately with the MAXENT model based on Worldclim and remotely sensed elevation data as shown by the high AUC values. Based on the strength of the present habitat model, if the model is applied on future climate scenarios, we also conclude that the geographic distributions of *Glossina*spp. may be reduced in the study are due to climate change.

It has to be noted that this study did not consider the ability of *Glossina* species to adapt to climate change. Factoring in adaptation may help improve the models and other environmental variables. Therefore, there is need for further studies that may include remotely sensed rainfall and temperature data as well as factor in species adaptation in the models.

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Testing gum arabic as potential binder in charcoal briquetting

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ABSTRACT
In this study gum arabic was tested as a potential binder in charcoal briquetting. Its properties harvesting methods and uses were described. Maize stalks were converted into charcoal and then pulverised. A solution of gum arabic was prepared using water as a solvent. Briquettes were made from various composition ratios of gum arabic solution and pulverised charcoal which resulted in the following ratios on dry basis 20% :80%, 30% : 70%, 40% : 60%. The composition which yielded best results was 30% :70% when tested for quality mainly against resistance to the absorption of water, wear, shock and pressure. The briquettes succumbed to a pressure greater than 24225 g/mm^2 as compared to sugar molasses briquettes which succumb to a pressure greater than 19225 g/ mm^2 .The briquettes were found to have negligible water content. The results indicated that gum arabic is a potential binder in charcoal briquetting. However further tests should be carried out to compare the cooking efficiency of the gum arabic briquettes in stoves with those of sugar molasses.

Key Words: gum Arabic, binder, briquetting, sugar molasses.

INTRODUCTION

Background

Environmental issues of public concern in developing countries are reduction in agricultural wastes and correcting environmental damage from the use of fossil fuels [1]. Agricultural wastes like maize and cotton stalk take time to decompose in the fields after harvesting period and become a nuisance in the next planting season. Studies have shown that biomass crop residues contain energy enough for domestic use [2]. Unfortunately the state of agricultural residues is not suited for direct combustion in cooking stoves. The residues need to be upgraded by agglomeration methods to produce dense charcoal briquettes which are of high energy value [3]. These briquettes can directly

replace wood, charcoal, coal and other fossil fuels used in many developing countries for cooking and heating purposes [4]. There use can also replace wood and save many forests that are dwindling and also help to mitigate against climate change giving value to an otherwise wasted material [5]. Employment is likely to be created in rural areas as the briquetting machines have to be housed in the rural areas and work force for the production and maintenance of charcoal kilns, briquetting equipment and adapted stoves will be needed.

In agglomeration a binder is used to glue particles of charcoal together. A binder that has been proved by experiments to give good briquettes is sugar cane molasses but it is not everywhere readily available [4]. Its availability depends largely on the presence of a sugar producing factory. Where it is available it has been found to have several competing uses, for example in Zimbabwe it is used in alcohol and animal fodder production. In such cases where demand exists, the molasses is expensive and consequently has negative effects on the price of briquettes. In countries like Sudan where alcohol production is prohibited sugar molasses does not have any use hence it can be acquired at no cost [5].

Research has shown that several potential binders have been tested in briquetting to include starch, clay, and water – glass (sodium silicate. None of these have produced acceptable results as starch bound briquettes were found not to be water resistant, clay bound briquettes were too brittle and water – glass made briquettes do not burn at all [4].

Commercial production process of briquettes

Agglomeration is a method of size enlargement by gluing powder particles together to produce spherical agglo-briquettes of diameters in the range of 25 -35 mm. The process involves five stages as shown in Fig. 1.

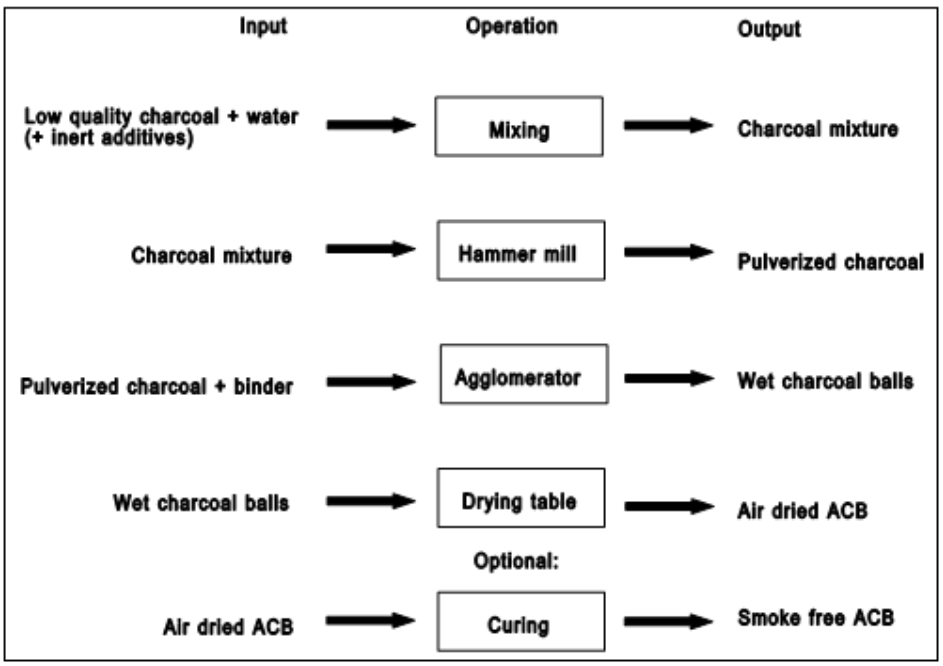

Figure 1: production process of agglomerated charcoal briquettes [4]

Charcoal is mixed with a certain quantity of water before it is milled in the hammer mill. This is done to prevent spontaneous ignition and dust .The charcoal powder is mixed with a binder and water and is sent to an agglomerator.

Figure 2 shows the structure of the agglomerator which includes a rotating container and a scraper.

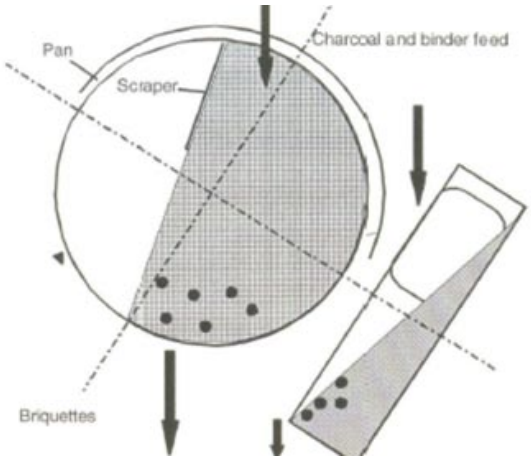

Figure 2: Top view of a rotating pan agglomerator [4]

The rotation of the container results in centrifugal, gravitational, and frictional forces. These forces cause a smooth rolling of the balls. The same forces together with inertial forces press the balls

strongly against the powder. Due to this pressure the powder sticks to the balls and as a result the balls grow layer-wise in diameter. The scraper is adjusted to prevent the charcoal feed from sticking to the walls and to direct the movement of the charcoal mass to the desired direction. The nucleus formation can be stimulated by a sudden increase in binder flow. The disturbances of the size distribution of the balls in the agglomerator are minimised by manually adding or removing the balls using a shovel. The balls can then be recycled later.

Since the agglomerator produces wet briquettes there is need to dry them. The charcoal briquettes are placed on an iron mesh mounted on a table for atmospheric drying. The drying time depends on atmospheric conditions. In sub-tropical climates it takes 1-2 days to dry the briquettes. If molasses has been used as a binder, the briquettes undergo heat treatment to produce smoke free products.

Properties of gum arabic

Gum arabic is a naturally occurring product that is exuded from stems and branches of several species of trees notably the acacia [6].Table 1 shows the physical and chemical properties of gum arabic.

Table 1: Physical and chemical properties

Physical properties	Chemical properties
• Solubility in water : top quality is 100% soluble in water on dry basis • Solubility: can dissolve in water at concentrations higher than 5% • Produces highly stable emulsions. • Available in tears, crystals or granules. • Physical form: tan liquid, viscous. • Tasteless, odourless and colourless (top quality) to pale straw colour (average quality) • Boiling point : 212º C • Specific gravity : 1.06 (water = 1) • Calorific value: between 5 and 8 MJ/kg • Ash content: 4%	• Gum arabic is a mixture of salts of calcium, magnesium, and potassium together with arabic acid. • Reactivity data : stable • Conditions to avoid: N/A • Hazardous decomposition products: none • Hazardous polymerisation: will not occur • Incompatibility: strong oxidisers

Harvesting

Gum arabic is harvested by making a wound on the branch or trunk of a tree using a traditional tapping axe or hunting spear. The gum oozes out from the wound and takes about three weeks to dry after which it is collected by hand [7]. Further collections are made at three weeks interval. This harvesting method is environmentally friendly since it does not encourage deforestation though the method is demanding.

Uses

In some countries gum arabic is used as an ingredient in a variety of soft drinks, in baking and confectionery items, in dietary fibre products, in cosmetics and in pharmaceuticals. In other countries it is used in the manufacture of adhesives that are used in bookbinding [7].

The objective of the study

This study is about testing gum arabic as a potential binder in briquetting of agricultural waste (maize stalks).

STUDY MATERIALS AND METHODS

Preparation of charcoal powders

The charcoal used in this study was prepared from maize stalks. Water of mass 10% the mass of measured charcoal was added to the charcoal to avoid spontaneous ignition during pulverisation. It was also a measure to prevent fine charcoal particles from escaping into the atmosphere. The pulverisation was done leaving particles with diameter range between 0 and 1 mm. This variation in particle size allowed for maximum packing of the charcoal particles during agglomeration.

Briquette composition and dough preparation

Fresh, good quality briquettes made of charcoal and sugar cane molasses consist of 40% water and 60% binder and charcoal [8]. The same briquettes on dry basis contain 20% binder and 80% charcoal. Consequently the ready briquettes on wet basis consist of 40% water, 12% binder and 48% charcoal.

The preparation of briquettes was based on the above composition as a guideline. The briquettes were made by hand since the limited amount of raw materials available did not allow the use of an agglomerator. The process involved the moulding of the dough in such a way that optimal packing

of the particles was achieved by positioning of small particles between the big ones. This was done by rotating and pressing the dough by hand into spheres of approximately 30mm in diameter.

Preparation of gum arabic briquettes

Initially equal amounts by mass of gum arabic and water were mixed and additional water added to dissolve gum arabic and this resulted in the following composition.

- 67% water
- 33% gum arabic

Still there were particles which did not dissolve so additional water had to be added but the total amount of water in the gum arabic solution was not to exceed the total amount of water for the dough. Calculations for additional water were made using a spread sheet in such a way that as much water as possible was added to the gum arabic solution and a minimum amount of additional water for the final dough.

The final gum arabic solution used therefore consisted of 74% water and 26% gum arabic, and the dough with the minimum amount of additional water consisted of 46% gum arabic solution, 53% wet charcoal and 1% additional water.

Additional water was to be added to the 67% - 33% gum arabic solution so as to get the desired composition with the help of spread sheets.

The influence of high gum arabic content on the quality of the briquettes was investigated with different compositions as shown Table 2, based on the 74%-26% gum arabic solution.

Table 2: Variations in dough composition

Ready briquettes on dry basis	Dough composition on wet basis
1. 20% binder (gum arabic) 80% charcoal	40% water 12% gum arabic solution 48 % charcoal
2. 30% binder (gum arabic) 70% charcoal	- 15% water 42% gum arabic solution 69% charcoal
3. 40% binder (gum arabic) 60% charcoal	-28% water 92% gum arabic solution 36% charcoal

The minus sign in the dough compositions of 2 and 3 above indicated the amount of water to be removed. The water was removed during the drying process of the briquettes. The briquettes were put in an oven set at temperature of 100ºC for total drying.

2.4 Heat treatment of briquettes

This was done in order to make the briquettes to become smokeless, water resistant and strong. The method involved the application of heat to the briquettes under moderate temperature. The temperature of the oven was set at 250ºC [8]. The different types of briquettes were put in the oven until temperature of 250ºC was achieved. The briquettes were then kept in the oven for a period of 15 minutes. Care was taken to avoid sudden rise and fall in temperature during heating and cooling as this would result in the cracking briquettes.

Testing of briquettes quality

Shock and Pressure

Briquettes that succumb easily to shock and pressure are said to be of poor quality [4]. In most cases they are found to be brittle and hence lose a lot of their material during transportation and handling. Fig. 3 below shows the arrangement of apparatus used in the testing.

Figure 3: Testing of briquettes apparatus

At contact points between the balance and the briquette and between the briquette and the bar were rubber surfaces of $1mm^2$ in area. Therefore any force on the briquette was acting on a unit area. A weight was placed and moved along the bar until the briquettes became crushed or developed cracks. At this point the value of the breaking pressure was recorded using the balance. This value was compared with those of known quality briquettes for example sugar molasses.

Absorption of water

Briquettes have to be stored during rainy season and if they absorb a lot of water their energy value is reduced. The briquettes prepared were weighed and put in an oven. A container filled with water was placed at equidistant to the briquettes and the oven temperature was set at 40 ºC and after 4 days the masses of the briquettes were measured. Mass of water absorbed by the briquettes was calculated and the water content obtained.

RESULTS AND DISCUSSIONS

Briquette composition and dough preparation

The briquettes of composition 1 were found to be too brittle. This meant that the briquettes could turn into powder easily during handling of which a lot of charcoal material is lost in the process. The briquettes of composition 2 were affected by high rate of drying and therefore developed cracks. Another set of briquettes was made and the rate of drying was reduced by lowering the temperature of the oven to 45ºC. The briquettes did not develop cracks. The dough of composition 3 contained a lot of water and therefore it was difficult to mould good round briquettes.

Quality of briquettes

The gum arabic charcoal briquettes of composition 2 succumbed to a pressure greater than 24225 g/mm^2. Studies had shown that sugar molasses briquettes succumbed to a pressure greater than 19225 g/ mm^2[5].From the results above gum arabic briquettes are more resistant to pressure than sugar molasses briquettes. This means they can be transported from one place to another without losing their material.

Absorption of water

The briquettes were found to have negligible water content. This means that the briquettes when left exposed to the outside environment they do not absorb water hence they maintain their energy value and burning rate. During burning moist briquettes lose energy in evaporating water in them.

CONCLUSION

Gum arabic has the potential to produce good quality briquettes with the following composition by weight on dry basis: 30% gum arabic and 70% charcoal. The use of gam arabic in briquetting can eliminate environmental problems caused by agricultural wastes.

RECOMMENDATIONS

Gum arabic should be adopted as a binder in charcoal briquetting of agricultural wastes, however further tests should be carried out to compare the cooking efficiency of the gum arabic briquettes with those of sugar molasses in stoves.

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A Robust Communication Protocol for a Stadium Turnstile Counting System

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ABSTRACT

For accounting purposes, and to prevent disasters due to overcrowding, it is necessary to count and limit the number of people entering a stadium. Rufaro Stadium in Harare, Zimbabwe, has a total of 36 turnstiles arranged in two groups of 6 turnstiles each and six groups of 4 turnstiles each. A control room below the VIP stand monitors all the activities on the 36 turnstiles. At each turnstile is a counter with a sensor which counts the number of spectators going through that entry point. The counter has a visible display in the form of large seven segment LED displays capable of counting up to 99 999 people. All the counters in a group, referred to as a cluster, are arranged in a wired ring network with a special cluster controller which collects the count values of its four or six counters through a robust local communication protocol. The control room communicates with the eight cluster controllers through radio signals and collects all the count information providing comprehensive information for the control room operator. The radio signals, which are transmitted at 490 *MHz*, must be immune to noise and other interference sources, mainly cellular communications. A robust radio communication protocol, which is an extension of the local communication protocol is used for this star point to point network with the control room as the central node. Comprehensive error detection with the use of a standard ITU 32 bit generator polynomial (CRC-32) is used to guard against errors during transmission at both the local and radio levels. The use of different preambles at the beginning of data frames improves the computational efficiencies of the different systems which are all based on the Microchip range of PIC microcontrollers – specifically the PIC16F876 and PIC16F877. A functional system has been developed and is now being used in football matches in Zimbabwe.

Key Words: stadium, turnstile, spectators, communication, protocol.

INTRODUCTION

Stadia across the world have known fixed crowd capacities. Sometimes these stadia are divided into sections usually referred to as ***stands***, and each of these has a fixed capacity. It is important to ensure that the total number of fans allowed into the stadium does not exceed its capacity. If this is not done, this can lead to a ***human crush*** as happened during the Hillsborough disaster in 1989 during the FA cup semi-final match between Liverpool and Nottingham Forest resulting in 96 deaths and 776 injuries. **(1)** Other stadium related disasters could be caused by the use of excessive force by the police in the event of bad behaviour by some of the spectators already in the stadium. Attendance at stadia can be controlled by the issue of tickets with seat numbers as is the case with most stadia in Europe. Mechanical counters can also be used to count the number of spectators who have entered the stadium. Such a system was installed at Barbourfields stadium in Bulawayo, Zimbabwe's second city. However, the officers in charge of the stadium have confirmed that the system was ever used only once and then it did not work properly. There are several suppliers of electronic counting systems for stadia. However, such systems, when imported are very expensive and beyond the reach of local stadia. It is against this background that the City of Harare, responsible for the day to day running of Rufaro Stadium in Mbare, a high density residential area in the capital city of Harare, requested SIRDC, the Scientific, Industrial Research and Development Centre, to develop an electronic turnstile counting system. The advantages of using local technological solutions include low cost and easy access to affordable after sales technical support.

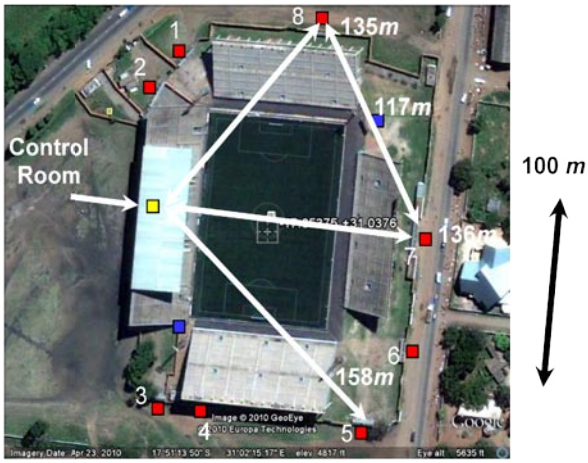

Figure 1 Google Earth map of Rufaro Stadium

Rufaro Stadium

Rufaro Stadium, with a capacity of 35 000 spectators, has a total of 36 turnstiles in eight groups which will be referred to as ***clusters***. Only two of the clusters have six turnstiles, while the other six clusters have four turnstiles each. See Figure 1, which is a Google Earth image of the stadium.

A turnstile is an entry point into the stadium which allows only one spectator to enter the stadium through it at a time. A kiosk operator allows spectators in a controlled manner to enter the stadium by pressing down on a foot operated pedal. The turnstiles only rotate in one direction and are normally locked until the pedal is pressed down. The turnstiles are numbered according to whether they are on the western, southern, eastern or northern side of the stadium. Each complete rotation of a turnstile allows three spectators to enter the stadium. The turnstile has a rotating part with the three sets of ***bars***and a fixed part.

Counting is based on the use of a magnet on each of the three arms of the rotating part and a magnetic reed switch on one of the fixed arms. Each time the magnet passes the magnetic reed switch, a contact (or short circuit) is created and this is detected by the electronic microcontroller on the connected counter. Each kiosk therefore has its own electronic counter with five large seven segment displays which can be read from a distance of more than 10 metres.

Microcontroller Technology

A microcontroller is a computer onachip. Several semiconductor companies have produced their own range of microcontrollers. These include Motorola, Intel, Zilog, Advanced Micro Devices (AMD) and Microchip to name but just a few. Development equipment and software is made available, supplied by these manufacturers at a cost. The Microchip range of microcontrollers has dominated the market because of its low cost, ease of access to and free software (downloadable from the Internet) and access to free programmers at the cost of the components required for the programmers. This range was chosen for this project because of its use at SIRDC for all projects. Specifically, in this project the PIC16F876 and PIC16F877 microcontrollers were used for all the hardware. A microcontroller interfaces with the outside world through ports which are commonly referred to as ***input*** and ***output*** or I/O. There are different types of input and output which support serial data transfers, parallel input and output for monitoring and control. A ***control program*** runs on the microcontroller in machine code and performs the required control function. PIC microcontrollers use a RISC (Reduced Instruction Set Computer) architecture with only 35 different instructions. Interrupts are used to handle time sensitive inputs. The counters in each kiosk next a turnstile use the PIC16F877 for controlling the display of five large seven segment displays using five external latches (interfaced to one output port) to store displayed data. Counting is done using the RB0 interrupt by detecting the falling edge created when the magnet passes over the magnetic reed switch sensor. The microcontroller uses its serial interface for communicating with other

counters and its own cluster controller to implement the ***local communication protocol***. However, to increase the noise immunity of the data transmission, the serial port is interfaced to a current loop system as opposed to the conventional MAX232 chip to change from TTL to RS232 levels. **(2)** Because current is used, and not voltage, the system is very immune to interference from adjacent electromagnetic sources. Figure 2 shows the current loop system adopted in the design. The design minimises the amount of power taken up by the serial communications by ensuring that when there is no data transmission and the serial lines are idling in the logic '1' state, no current is transmitted. The design also ensures correct and reliable operation on very long lines with a high electrical resistance through the use of a bipolar transistor at the receiving end which ensures that a fixed current is passed onto the receiving optocoupler.

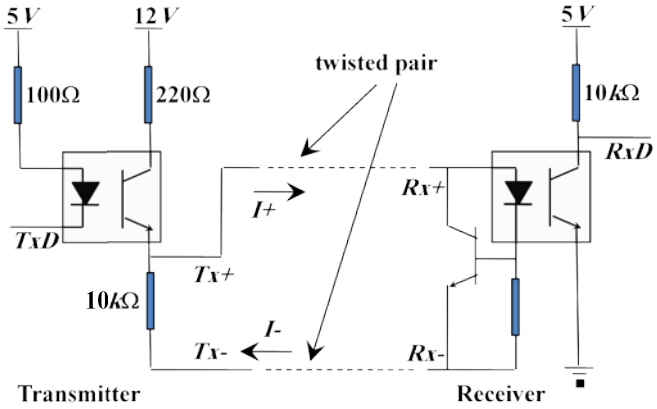

Figure 2 Current Loop Hardware

The control room station is similar to a basic counter in that it displays the total overall count on the large seven segment displays but it also interfaces with a hex-keypad and an LCD (Liquid Crystal Display) of 4 rows by 20 characters per row. The latter gives the control room operator access to a system which is capable of displaying comprehensive information.

Communications Infrastructure

A two level communications system was adopted. At the local level, within each cluster, a special unit, known as the ***cluster controller***, collects the count values from its four or six counters before forwarding them through radio to the control room station. A ring topology was used with twisted pairs being used between the nodes using current loop. The cluster controller uses serial communications using current loop and twisted pair for local communications. For communicating with the control room using radio, it also uses serial communications. The JZ881 radio transceiver was used on its serial interface. The cluster controller requires two serial interfaces. Because a microcontroller with two serial interfaces could not be identified, two PIC16F876 microcontrollers

are included in the design of the cluster controller hardware. These microcontrollers communicate with each other through their standard SPI (Synchronous Peripheral Interface) subsystems with the use of comprehensive ***handshaking***. The transparent JZ881 radio transceiver was selected because of its ease of use and an 800 metre range transmitted using the 490 *MHz* frequency band. Handshaking between the two SPI interfaces is used to ensure that data flow is consistent and is as fast as is possible because of the MASTER / SLAVE operation of the SPI interfaces and to prevent what are referred to as ***write collisions*** – really only possible on the SLAVE SPIs. **MASTER_REQUEST** and **MASTER_ACK**, **SLAVE_REQUEST** and **SLAVE_ACK**, **SPI_REQUEST** and **SPI_ACK** are the handshake signals used. Request and acknowledge handshake signals follow a fixed sequence. Both idle at '0'. First the request line goes active followed by the acknowledge line becoming active. The data transfer then takes place. After the transfer, the request line goes inactive followed by a similar transition on the acknowledge line, back to the idle state. See figure 3.

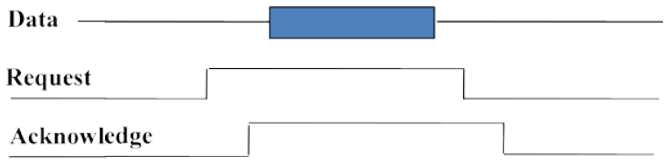

Figure 3 Handshake Sequence

A Robust Communication Protocol

Local communications starts with the cluster controller, which transmits a blank frame of a fixed format to the first counter which checks this for errors. If an error is detected, a negative acknowledgment (**NAK**) frame is immediately transmitted to the next counter downstream round the ring to increase speed of operation. A counter receiving a **NAK** frame will immediately forward it round the ring until its gets back to the cluster controller which transmits the next blank frame. The cluster controller will automatically transmit another blank frame if it times out, i.e. does not receive a frame from its immediate upstream predecessor after the expiry of a predefined timeout period since sending the last blank frame. If no errors are detected, the counter inserts its own uniquely assigned address (identification or number) and count value and forwards the frame to the next (or downstream) counter in the ring. After all counters have inserted their identities and count values, the cluster controller collects these and stores them in a table before onward transmission to the control room. Errors are handled using ***cyclic redundancy check*** (**CRC**), a very robust and reliable method of detecting transmission errors. **(3)** See figure 4 for the frame formats. Each frame begins with a start of frame delimiter (**SFD**), which is the byte **0x23** for the hash symbol, followed

by the length of the frame as one byte, counting all the bytes from the next one until the end of the frame. This is then followed by either a two byte field (represented as **0xPP** and **0xQQ**) in the case of ***management frames***, or the data field of count values for data collection frames. With data collection frames, three bytes are reserved for each counter, one byte for the address and two bytes for the count value giving a maximum of 65535 for the count value. This means that this field is either 12 bytes for four counter clusters or 18 bytes for six counter clusters. The four byte CRC field is next, which is immediately followed by the end of frame delimiter (**EFD**), the byte **0x2A** for the star symbol. To ensure that no serial data is lost, all serial data across the entire system uses interrupts. Superimposed on this frame format are additional bytes used to achieve synchronisation and rapid recovery from errors. The count byte following the start of frame delimiter has only three possible values at the local level. These are **0x07** for management frames, **0x11** for four counter clusters and **0x17** for six counter clusters. Sychronisation is achieved through the use of the preamble: **0x00 0x01 0x00 <u>0x06 0xA5 0x5A 0xA5 0x5A 0xA5 0x5A 0x06</u>. 0x06** is the **SYN** (Synchronisation) character in data communications. The active part of the preamble is underlined. The first three bytes in the preamble enable fast recovery from characters missed during transmission. A receiving system checks for a valid preamble, valid start of frame delimiter, and a valid length value before receiving the received frame into a buffer for storage.

Preamble	0x23	0x07	0xPP	0xQQ	CRC3	CRC2	CRC1	CRC0	0x2A

Management Frame Format

Preamble	0x23	0x11	ID0	CNT0_HI	CNT0_LO	ID1	CNT1_HI	CNT1_LO	ID2

CNT2_HI	CNT2_LO	ID3	CNT3_HI	CNT3_LO	CRC3	CRC2	CRC1	CRC0	0x2A

Count Update Frame Format

Figure 4 Local Frame Formats

Radio communication between the control room and the eight cluster controllers has its own unique problems. The first is interference from other nearby sources. The second is that if two radio transmissions take place simultaneously, these will overlap and a collision is said to have taken place.

This means that the intermingled data will be meaningless to intended recipients. The IEEE802.11 wireless standard provides for the use of the CSMA / CA (Carrier Sense Multiple Access with Collision Avoidance) scheme to prevent collisions. **(4)** This uses a four way handshake and a **comb** to minimise collisions. Such a scheme would have created a large overhead on the transparent transceivers used. In the radio communication protocol adopted for the counting system, collisions

are avoided by using a MASTER / SLAVE approach where the control room assumes the role of master and the other eight cluster controllers become slaves. The MASTER can broadcast messages to all eight cluster controllers or can request an addressed cluster to receive a message or request it to send a count update. A Slave can only transmit immediately after a request to do so, commonly referred to as a **POLL** in data communications. Any transmission from the master is received by all the slaves. Also, transmissions from any slave to the master are received by all the other slaves. To avoid unnecessary processing at the other slaves, two different preambles are used. One is transmitted by the master, and a different one is transmitted by all the slaves. Whereas the master transmits the preamble discussed earlier on, the slaves transmit the preamble: **0x00 0x01 0x00 0x06 0x96 0x69 0x96 0x69 0x96 0x69 0x06.** Radio frames include two additional bytes when compared to local frames immediately after the preamble. The first byte is the start of header (**SOH**) – **0x01,** as is standard in data communications. This is immediately followed by the cluster address. Cluster addresses are uniquely assigned values from a range different from that of counters. An address of all ones, i.e. **0xFF** is used as a broadcast address to communicate with all cluster controllers with the same message. Group addresses are also used: **0xFD** and **0xFB** to distinguish VIP clusters from the rest of the clusters. A group address selects clusters which share a common attribute. A message with a group address could, for example, be used to stop entry of additional spectators into the different sections of the stadium depending on their capacities.

Once every minute, the control room sends a request for count values (**RTS**) from cluster controllers in a round robin fashion. This is a management frame with the address of the recipient. The recipient either returns a **NAK** (Negative Acknowledgement) frame if it has no additional data since the last update, or it returns the latest count update. The latest count update, once processed, is displayed on the 4 rows by 20 character LCD display in the control room.

CRC Error Handling

Cyclic Redundancy Check using CRC-32, with the generator polynomial **0x104C11DB7,** was used. If a message is to be transmitted, four additional redundant bytes, i.e. 32 bits – hence the name CRC-32 (initialised to all zeros) are inserted at the end of the message. A Cyclic Redundancy Check computation is performed on the expanded message to generate a 32-bit Frame Check Sequence (FCS) which replaces the 32 appended zeros on the four additional bytes. The expanded message is transmitted and received by the recipient. The recipient runs the same computation on the expanded message. If the resulting frame check sequence is 32 zeros, the frame is deemed to be free of errors. A non zero frame check sequence signals a transmission error. CRC-32 is an ITU

(International Telecommunications Union) standard generator polynomial used in ethernet LANS for error detection and has a residual error rate of 1 in 10 billion! The CRC computation involves the long division of the message with the generator polynomial. The subtraction used during the long division is modulo 2 subtraction, i.e. the divisor and the aligned most significant part of the dividend are exclusive ORed. The Frame Check Sequence transmitted with the message is the remainder of that long division. The communication protocol ignores errors through discarding damaged frames. This is acceptable since the control room system always transmits requests for data periodically and frames lost due to errors are always compensated for by subsequent transmission of error free frames. At the local level, the cluster controller also periodically sends out blank frames, so any discarded frames will be followed by error-free frames with more up to date information.

Overall Software Design

There are a total of six different programs which run on the entire system. The first program runs on each counter, where the uniquely assigned physical address of the counter is hard coded. It is also programmed with the address of the first counter in its cluster and whether it operates on a four counter or six counter cluster. The second program runs on the control room station and is unique. Each cluster controller runs two programs, one for the PIC interfacing with the local cluster and another for the PIC with the radio interface. These are the two programs which handshake, to transfer frames in either direction using the handshake signals described earlier on using the SPI to SPI interface. The last two programs run on the control room controller, which is the same hardware as the ordinary cluster controller except that the two programs are different. A similar handshake mechanism is used for data transfer except that the role of SPI master and SPI slave are exchanged as far as hardware configuration is concerned. A number of different frames have been defined for operation from the control room station up to the transmission to cluster controllers.

Self Testing and Management Frames

The system goes through a self testing phase on power up. At the local level each counter starts in self test mode whereby all the bytes of frames circulating round the ring are displayed in hexadecimal using the two left most displays. This leaves the three right most digits for displaying the count value. The cluster controller sends a management control message after 64 cycles to move the counters into normal mode. This allows the operators to verify correct operation of the cluster – thus checking both the hardware and the software. Each time a frame is transmitted or received, the bytes are displayed and an experienced technician can verify correct operation. This allows the

maintenance engineer to fault find broken wires or faulty counters, or even a faulty cluster controller.

The control room station has a current loop interface to its controller which has radio communications capability. After power on, a control message is sent from the control room station to the controller and back. All control messages and updates being exchanged by the two units are also displayed on the two leftmost digits. This allows the service technicians to diagnose and fix any system faults.

CONCLUSION

A robust turnstile counting system was developed using affordable available electronic components. The main advantage of the system is that it is a local design meaning that there is available affordable and instant local after sales support. The same communication protocol can be used in other applications, e.g. allowing traffic light intersections to communicate to manage orderly flow of traffic in a city.

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SECTION III:

PROMOTING AND MAINTAINING GOOD HEALTH

Free but expensive: An assessment of healthcare facilities in remote rural and farming communities.

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ABSTRACT

Zimbabwe Government policy proclaims that most health provision shall be free of charge in rural and farming communities. These free services include consultation, maternity, medicines among others. However despite efforts to reach out to excluded communities with free and affordable healthcare systems, free medical service has only been on paper. On top of user fees still being charged, some health centres are charging a maintenance levy which may be paid as cash or in forms of materials like bricks. The dearest charge though relates to inaccessibility of health care services by some rural and farming communities. Using interviews at 15 health centres dotted around Zimbabwe's rural and farming communities, this research found out that the cost of travelling to health centres, sometimes with two or more other relatives, the cost of accommodation, the cost of food and the cost of medicines make healthcare very expensive. Further to this, those who are referred from primary healthcare centres for secondary or tertiary healthcare face daunting challenges. Resultantly, they fail to access healthcare that is free to them because it becomes too expensive. Based on these findings, this research recommends an enhanced free healthcare package which meets all the needs of the disadvantaged patient.

Keywords: healthcare, rural, farming communities, tertiary,

INTRODUCTION

Health delivery is a crucial element that contributes significantly to human development. Thus, realising the importance of health care, the Government of Zimbabwe supports health for all its citizens. Cognisant of the fact that some of its citizens may be unable to meet the cost of health care, the government introduced policies to make health care available and affordable. Such policies also benefitted rural and farming communities which were provided with the infrastructure for health care among other health related services. Rising levels of health care has seen Zimbabwe

being ranked one of the best in Africa in terms of health delivery. However, this trend waned during the last decade owing to a number of factors, among them economic collapse and sanctions imposed on the country.

Health delivery in rural areas of Zimbabwe

Public health in rural Zimbabwe is coordinated by the Ministry of Health and Child Welfare (MHCW). At the grassroots level, the health system consists of village health workers who are part of the primary health care system. These workers work with a primary healthcare facility, normally a clinic run by a nurse in charge. At the clinic, a community health nurse working with an environment health technician coordinates community health efforts like awareness and surveillance (1). Each clinic in Zimbabwe is expected to service 10 000 people within an 8km radius. However, this has not been achieved, some patients travel for more than 10km to get health care (2). This situation has been made worse by the low numbers of village health workers and reduction in mobile clinics.

Each clinic reports to a District Hospital normally situated at a growth point. This is a referral centre at district level serving all clinics in the district. Each hospital is expected to cover 140 000 people. The district hospital refers patients to a provincial hospital which in turn refers to quaternary or national (sometimes referred to as central) hospitals. The provincial hospital is situated in the provincial capital, normally taking more than 4 hours of travelling on buses charging between $4 and $15 whilst national hospitals are found in Harare and Bulawayo and journey to these hospitals cost $10 on average. Journeys to national hospitals may take several hours, some close to a day. In rural areas, there are limited private health facilities normally situated at growth points. There are not normally accessible to rural people because of the costs involved.

Alternative treatment in rural areas include faith based methods (praying, prophets and others), traditional based methods (exorcism, n'angas, herbalists or others) and Chinese medicine (tiens, ceragem and others).

In the main, people in rural areas have poor access to health care because of a number of reasons. The basic reason is poverty. Poor people have several needs, and health care competes with the need to secure food, education and livelihoods (3, 4). In this regard, the Government of Zimbabwe proclaims that health care services must be free of charge to poor people in Zimbabwe. This proclamation seeks to increase the number of rural people seeking health services. Free services

include consultation, medication, specialist services where available, accommodation, counselling, tests, and home visits among others (1).

Other services provided by primary health care centres, according to MHCW are basic but comprehensive promotive, preventive, curative and rehabilitative care, concentrating on mother and child care including antenatal care, delivery of uncomplicated births, family planning, child health and nutrition, routine immunization for children and anti-tetanus immunization for child-bearing women, environmental sanitation, especially in relation to small-scale water supplies and excreta disposal systems, control of communicable diseases , other specified problems including mental illness, eye diseases and physical and mental handicap, and general curative care including oral health (1).

However, besides being affordable, health care also has to be accessible, acceptable, appropriate and available (5, 6). Studies detailed here tended to focus on availability of healthcare services at the expense of other determinants. This study looked at neglected factors as they impact delivery of health services in rural areas. Such neglected factors may be better understood by looking at the Four A's Model that shows determinants of successful healthcare. The model is illustrated and described in the proceeding section.

Conceptual framework

This paper was informed by the Four A's Model of healthcare which was advanced by key stakeholders in heath, among them the World Health Organisation (7). The Four A's Model is based on the assumption that success of health delivery strategies and innovations is determined by its acceptability, affordability, availability and accessibility.

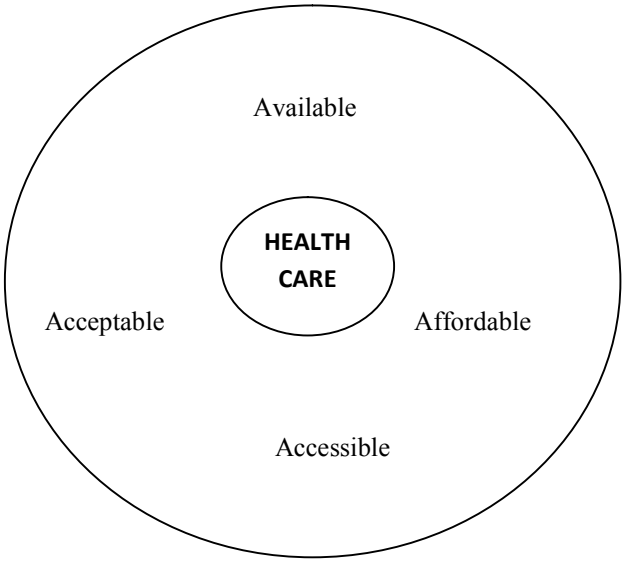

Figure 1: Four A's Model of Healthcare

In line with this model, healthcare services can only be successful if they have all the four A's. The model has been equated to a wheel of life which should be balanced for any human being to achieve efficiency.

OBJECTIVES

The broad objective of this study was to explore reasons why people in rural and farming communities do not seek health care services in spite of these services being provided free of charge at public health institutions. The specific objectives were to:

- Assess the affordability of health services.
- Explore the availability of health services.
- Examine accessibility of health services.
- Assess the acceptability of health services.

METHODOLOGY

Study population and sites

The results of this research were derived from a three months study of health institutions in rural and farming communities. Fifteen primary and two secondary health care facilities formed part of the study and these were derived from Buhera and Hwedza Districts. Buhera is a largely rural district with an estimated total population of 218,570 people (8) whilst Hwedza has a combined rural and farming area with an estimated population of 90 350 inhabitants (9, 10). In total, Buhera has 30 primary health institutions whilst Hwedza has 10, five of them in farming or former commercial farming areas. Two district hospitals were included in this study. These were Murambinda Mission Hospital in Buhera and St Mary's Mission Hospital in Hwedza. These are all Catholic Mission Hospitals but designated government district hospitals. Rural inhabitants of study sites are poor people who struggle for a living through subsistence farming in Buhera and subsistence to commercial farming in Hwedza (8, 9). Buhera, like the central part of Hwedza, is a dry area whilst the southern part of Hwedza, which used to be a large scale commercial farming area, receives favourable rainfalls.

Sampling

Buhera and Hwedza districts were selected since they provided health facilities in rural (Buhera) and commercial farming areas (Hwedza). The two districts are adjacent and they are linked by a good road network. The two districts have a combined population of about 390 000 and a total 42 of health centres. Generally, the sample can represent the situation in most rural and farming communities of Zimbabwe but cannot be taken as representative of the whole country.

Fifteen health centres took part in the study (Appendix 1). In Buhera, the researchers used simple random methods to select 10 health centres. In Hwedza, a total sample of health centres in commercial farming areas was achieved since all the five centres fitted this inclusion criterion. Each centre provided a single respondent, in all cases the most senior health worker. On top of these, three medical officers were interviewed (two from Buhera and one from Hwedza) based on availability. Resultantly, 18 respondents who included five environmental health workers, 10 nurses and three medical officers were interviewed.

Data gathering

This study relied on data gathered by the researchers from health workers. In-depth interviews were done with all the 18 respondents. An interview guide (Appendix 2) was used with all respondents. Eleven of the respondents were interviewed at the district hospital during their routine visits whilst seven were interviewed at their health centres.

Ethical considerations

In applying this methodology, research ethics of confidentiality and informed consent were successfully applied. Respondents participated in the study after consenting. Before each interview, interviewers informed respondents about the purpose of the study, explained that participation was voluntary and that all data gathered was not going to be released to other parties.

Data analysis

Data was analysed using themes corresponding to the Four A's model. However, some data remained unclassified under the four A's resulting in the authors classifying the extra data into two themes that were named appropriateness and alternativeness. Thus, two more A's were created resulting in adaptation of the Four A's model into a Six A's model.

Limitations

The major limitation of this study is sidelining of quantitative techniques in data collection and analysis. This study could have been stronger had it increased the number of respondents and health institutions covered. It could also have improved results if it had included users of health services as respondents. These limitations were difficult to overcome given resource limitations at the time. To address shortcomings of this study, a follow up and complementary quantitative study targeting 200 rural households is ongoing. This study seeks to assess the Six A's model of health service delivery

in these two study sites from the perspective of villagers and farmers who are the consumers of health services.

RESULTS AND DISCUSSION

The findings of this study are presented in seven sections: affordability of health services; availability of health services; accessibility of health services; appropriateness of health services; acceptability of health services; alternativeness of health services and summary of findings. After each result is presented, a discussion follows.

Affordability of health services

At primary level, consultation was free of charge. However, 10 primary health care centres charged a levy of between $1 and $3 for construction, security and repairs. It was explained that such levies were not strictly on cash basis. Villagers could pay in forms of bricks or labour. Health workers agreed that although this was a community approach that induces participation, some households could not afford such levies and they end up not attending health centres for critical health services. This supports the views given by the researches on poverty and health delivery in Zimbabwe (2, 3).
Village heath work services were free of charge. This is in line with government policy (1). However, respondents said village health workers normally seek various rewards for the health services they give. For example, one respondent reported to the clinic that they paid 'some few South African rands' to incentivise a VHW to give health information. Another nurse reported that VHW normally gain 'socially' that is they get certain favours in the community like free labour or free beer. Respondents concurred that VHW were not coercive in terms of seeking rewards but used their opportunity to increase their social capital or influence.

At District Hospital level, consultation was free of charge. The health workers explained that although at some district hospitals in Zimbabwe, there were some charges, at Murambinda and St Marys they were not charging because as mission hospitals, they receive donations from their churches and from other associations. The nurses interviewed pointed out that the major challenge at this level is accommodation of long term patients and those accompanying them. At times, the accompanying person sleeps in the open. When there are more patients at the hospital, some patients are forced to go home and attend treatment sessions as outpatients. This affects the treatment process and may promote not-compliance (4).

Whilst HIV/AIDS services were found to be affordable, they were affected by lack of funds for follow up visits to collect free ARVs. This reinforces earlier findings on lack of access to health care (5).

Availability of health services

VHWs were not active in most villages, although the number of villages was not established. Maternity nurses and environmental health technicians were available at 4 primary health centres. Doctors were in most cases overloaded with patients, concurring with previous researches (5).

All facilities lacked adequate supply of essential medicines. This resulted in patients seeking such medicines from private pharmacies where they are very expensive (4). For example CPZ tablets were not available at Murambinda Hospital. Surrounding pharmacies had no stock too. It was available from Harare at a cost of between $3 and $6 for a month's supply (adult prescription of one tablet a day for a month). Resultantly, people defaulted taking their medicines or moved on to alternative treatments. One respondent gave a case of a sister who used to break tablet into four pieces so that she could give her brother for a lengthier period of time. This was attributable to the brother's relapse since he was a psychiatric patient.

Each health centre in Hwedza and Buhera served approximately 9000 and 10 000 people respectively. The district hospitals covered about less than 90 000 and less than 200 000 people respectively in Hwedza and Buhera. It should be noted Hwedza has a rural hospital at Hwedza whilst Buhera has two smaller hospitals, one at Buhera offices and another one at Birchnough Bridge. These small but extra hospitals reduce the catchment areas for the designated hospitals. In this case, the researchers reduced the total catchment for the designated hospitals. The Government of Zimbabwe anticipates that each primary care clinic must serve 10 000 people whilst a district hospital serves 140 000 people. It anticipates everyone to be within 8km, ie walking distance to a health facility. Respondents noted that whilst most residents live within this radius, there are other villages that are even over 15km away from a health centre. The Access to Health Care Services Study of 2008 found that most communities live within a 5km radius of their nearest health facilities, 23% between 5 to 10 km, and 17% over 10km from the nearest health centre.

Accessibility of health services

Respondents concurred that villagers who live in areas where they need to pay for bus fares to access health services, especially specialist services, normally end up not accessing such services or

delaying accessing it. Areas with very poor transport networks were seriously affected since transporters charged exorbitant prices or were not available every day. This view has been put before and reduces uptake of health services and products (1, 2). The Maternal and Perinatal Mortality Study of 2007 noted that only 52% of rural women delivered in health facilities compared to 94% in urban areas. This difference was caused mainly by the difficulty rural women faced in reaching a health facility.

Awareness about the availability of health services was said to be unavailable to some villagers. One nurse said some villagers did not know that there was medicine to treat conditions like epilepsy. One doctor argued that some villagers were unaware that family planning was free, a view supporting earlier findings and recommendations on the need for appropriate information and communication technology for health.

Acceptability of health services

Respondents agreed that some apostolic sects do not accept modern medical treatment. This was popular among the Johanne Marange sect. The disbelief in modern treatment is a doctrine that is supported by faith healing. It is also motivated by lack of confidence in modern treatment practices. Another example was given on condom use which was low and at times rejected by some villagers who argued that it shows elements of mistrust and infidelity in a relationship. Respondents agreed that condom use was not acceptable among adult populations.

Yet another example was given by respondents on unacceptability of surgical treatment. Nurses interviewed agreed that among the rural people, surgical treatment is viewed with suspicion and some families opt not having it done on their family members.

Health workers who were involved in immunisation strongly concurred that immunisation was not acceptable amongst some churches. This was so because of the belief that '*vana vanochengetwa namwari'*.

Appropriateness of health services

Village health work was rated as appropriate as it was promoted by people who already know about the beliefs and attitudes of the local people. One doctor said VHW are trusted and may provide acceptable services. He said they were using VHW to promote behaviour change. This strategy has

also been recommended by another WHO and other researches on the uptake of health services in Zimbabwe (6).

Some health workers questioned the appropriateness of doctors who do not speak or understand Shona but working with a Shona speaking population. Such doctors normally come to these hospitals on short to medium term basis and the local people at times find the communication barrier too huge. Suspected cases of misdiagnosis were reported.

The appropriateness of current approaches of health care towards people who resist them e.g. Johanne Marange sects was questioned. Those interviewed had different views. Others said those who resist treatment for cholera and HIV/AIDS must be forced to receive it and laws must be put in place to make them comply. Other respondents thought otherwise, arguing that there was need for dialogue. Dialogue has also been the focus of MHCW although it resorted to force in Buhera during previous cholera outbreaks (1).

Alternativeness

Respondents said modern treatment presented no alternative methods of treatment to villagers. They argued that traditional methods were not accepted by the health system and that religious faith was also said to derail modern treatment for example it reduced health seeking behaviour. On the other hand, Chinese medicine was not accepted by health workers although the villagers flocked to Tiens Centres with some being referred to Harare at various Ceragem centres where they sleep in the open and queue to be attended.

However, respondents agreed that whilst the system does not integrate with traditional methods, villagers use these alternatives on a daily basis. Thus, there is conflict between the system and the views of the villagers.

Summary of Findings

After assessing health delivery in Buhera and Hwedza, researchers summarised results by adapting the initial 4 A's framework into a 6 A's wheel of healthcare presented on Figure 2.

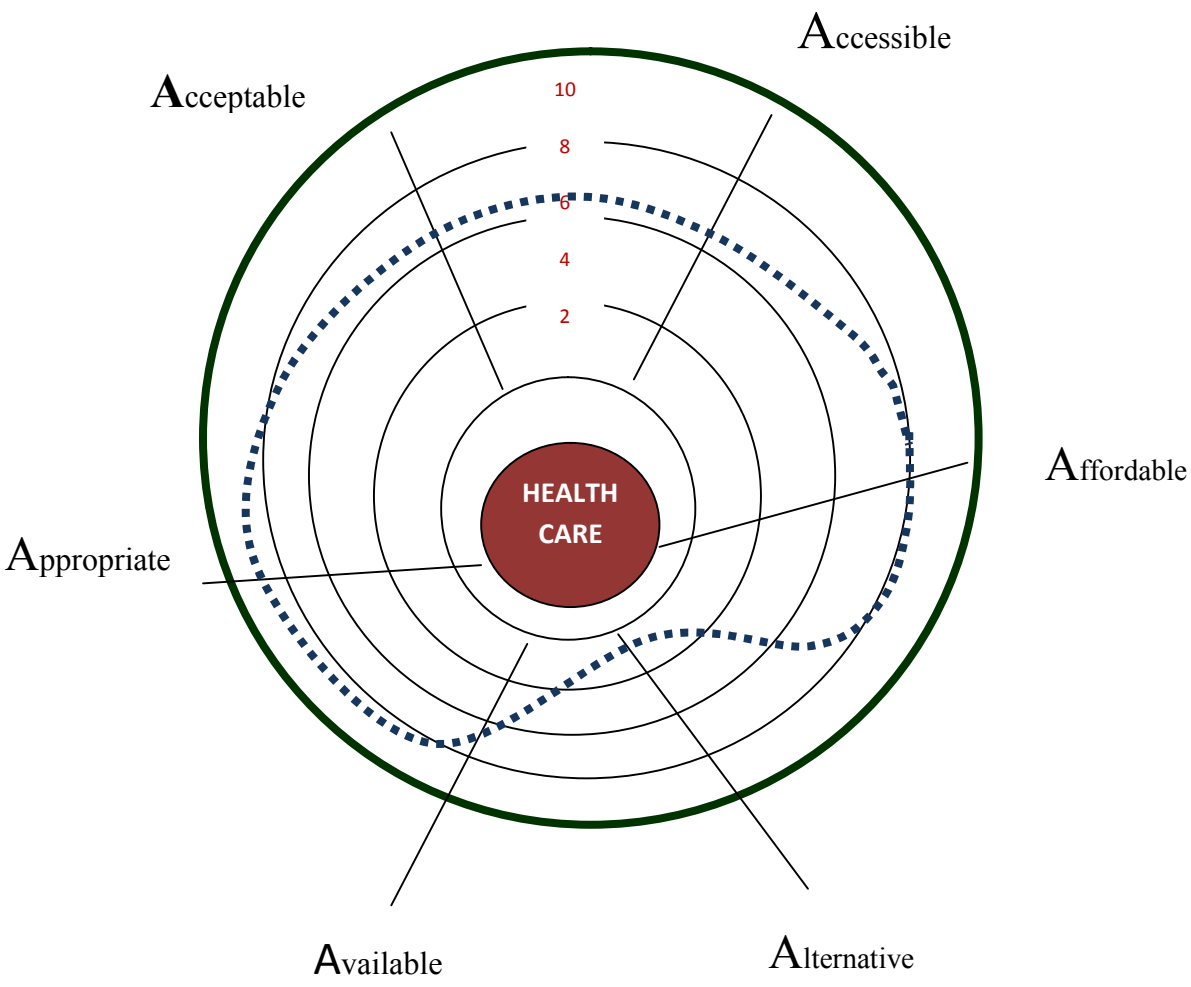

Figure 2: 6 A's Wheel of Healthcare

J. Mugumbate et al. Proposed 6 A's model of health delivery.

This model is an improvement of the Four A's model. It includes two more A's and a scale to measure the level at which an A is considered to exist within a community. Though applicable in a more quantifying study, the scale is an approximation of the balance that exists in health care systems. Each A is quantified on a scale of 1-10 based on the recurrence of selected themes. The most desirable level of the wheel is shown by a green bold continuous line. The estimated level for studied communities is shown by a blue dotted line. The graphical presentation shows that wheel of healthcare in the studied communities was not balanced.

CONCLUSIONS

In the main, the authors conclude that health services in rural and farming communities do not meet all the 6 A's required for successful health delivery. Health services that are only affordable, like

those in Zimbabwe, and not accessible, available, acceptable and appropriate, are actually very expensive. Further conclusions are stated below:

- Generally, public health services are affordable in rural and farming communities. However, for those who require extra resources to reach health facilities and to access them, health services become expensive.
- Primary and secondary health care services are not readily available to rural and farming communities. Major services lacking include doctor's consultation and specialist services.
- Health services are not readily accessible to residents of rural and farming communities.
- Health services are not all acceptable in rural and farming communities.
- Appropriateness of health services is an important factor which determines uptake of health services. Health services that are not appropriate were not readily consumed by people residing in rural and farming communities studied.
- Alternative methods of therapy are neglected. Alternative methods of managing ill health must be integrated into the health delivery system for them to improve instead of keeping them at the periphery of the system.

RECOMMENDATIONS

In light of these findings, authors would like to broadly recommend provision of comprehensive health services in rural and farming communities. Such service provides a balanced wheel of health delivery. Further recommendations are as follows:

- Provision of free accommodation at health centres to reduce costs.
- Resumption of mobile health services in villages.
- Facilitation of visiting doctors at rural health centres.
- Increasing the number of village health workers.
- Provision of incentives to village health workers.
- Reducing distance from health centres by increasing the number of health centres.
- Integrate churches and traditionalists who do not believe in modern treatment and improve health laws to ensure compliance and integration.
- Monitor Chinese medicines.
- Improving transportation and communication systems.
- Grassroots mobilisation and education to increase health seeking behaviour.
- The research recommends the following areas for further studies:
- Examine the concept of *mapiritsi anaouraya* (modern treatment kills) and its effects towards health seeking behaviour.

- Consider alternative strategies used by people in rural and farming communities to get health services.
- Examine strategies of health promotion being used by public institutions in communities that have low health seeking behaviour.

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Electronic Health Records and their role in the revitalisation ofhealth delivery system in Zimbabwe

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ABSTRACT

A sound health delivery system rests on the availability and effective management of health records. Given the emergence of Information Technology and its applicability to health information management around the world, coupled with ever increasing computer literacy skills among the world's population, this paper presents that Electronic Health Records (EHR) can go a long way in facilitating the revitalisation of the health delivery system in Zimbabwe. Drawing from case studies that have been conducted by other scholars around the world and literature on the positive impact that EHR have had on health delivery systems, the potential of EHR to improve health delivery system in Zimbabwe is discussed. We conclude by urging the Zimbabwean government, in the endeavour to revitalise the health delivery system in the country, to consider and implement EHR

Keywords; electronic health records, health information, computer literacy

INTRODUCTION

Effective health records management practices underpin health delivery systems. The need for effective ways of making information contained in medical records readily available to all healthcare stakeholders is ever increasing in a country such as Zimbabwe which is characterised by perennial problems of high infant mortality rate and HIV prevalence. Zimbabwe has a high HIV prevalence of 13.7%, a weakened health system in the midst of poor economic performance, and droughts (1).

The country also ranks within the top 50 countries in the world for high early childhood mortality (2). Amid such revelations, it is crucial for health information to be readily available and accessible within the shortest possible time to medical practitioners, governments and patients themselves.

Information Technology (IT) has revolutionised virtually every facet of our lives (3). Information is necessary for the provision and management of healthcare at all levels, from individual patients to health care systems to the Ministry of Health (4). IT application to healthcare is a major global issue that has triggered a marked amount of research (5). Electronic Health Records (EHR), which are also known as Electronic Medical Records (EMR) play an important role in facilitating the availability of health or medical information to a wider population of medical practitioners. Efforts to revitalise the health delivery system in Zimbabwe can reap huge benefits from EHR systems. Thus, modernising health care systems with Electronic Health Records is a critical need of in health reform effort (6).

Organisations of all types have long seen that IT- viewed comprehensively and deployed effectively has a potential of replacing challenges with new opportunities (7).

The implementation of EHR would come handy in the case of Zimbabwe especially in view of the growing computer literacy skills among the country's population. Zimbabwe is one of the countries in Africa that enjoys a steady growth in the reception of ICTs by the population. Researchers in Africa predicted African mobile subscribers to grow at 22% from 113.55 million in 2005 to 378.62 million by 2011 (8). The rate of growth for the entire continent has been more than 82% a year, much faster than the growth rate in the Americas (9). Internet access is now relatively widely available in many developing countries (10). The level of information and communication technology among Zimbabweans has risen to 72% as the country continues migrating from analogue to digital (11).

These positive developments, coupled with efforts by the government through the Ministry of Information Technology to improve the state of telecommunications infrastructure in the country establishes a sound foundation on which EHR can be implemented. Information and Communication Technology deserves a pivotal and enabling role in any development strategy considering that since late 1990s, there has been unprecedented increase in access (12). As a country, we need to be ready and prepare ourselves in ICTs to regain the missed opportunities and neglected advantages of the past decade of our national challenges (13). Indeed Zimbabwe has missed out on great opportunities that ICTs to the healthcare industry in the form of EHR.

In healthcare practices of all types and sizes, information is both a benefit and a challenge in the sense that new information about disease and treatment is saving lives, while a lack of effectively

managed data can put this information at risk (14). The unavailability of complete and timely health information has been a major problem for the healthcare industry in Zimbabwe.

Health information is increasingly less complete at District, Province and National levels, because of failure to update late returns received at lower levels (15). Amid such reports, robust health records and information management systems are indispensable if the country is to meaningfully revitalise the health delivery system. The thrust of this paper is the need for better and more efficient and effective ways of capturing and making available, health information to all the concerned stakeholders for health delivery systems in Zimbabwe.

An EHR- what it is?

Although EHR/EMR is a fairly new concept (16), literature abounds on the subject matter. An EHR comprises a set of comprehensive database used to store and access patient's healthcare information (17). Ideally, a universal EHR will be a seamless patient record that crosses the continuum of care (18).

An EHR is a collection of health information that has been gathered by and is managed by an enterprise-typically a doctor's office, a hospital, or an integrated system (19). Thus, an EHR system is a package that enables the capture, navigation, updating and sharing of a patient's health information. In healthcare systems today, a patient might have several EHRs under the control of various organisations (20).

Objectives

The objective of this study was to discuss the concept of an EHR and the potential to facilitate the revitalisation of the health delivery system in Zimbabwe. This study was prompted by the scantiness of literature on EHR in the country, yet there is evidence of tangible benefits of EHR in other countries. This study aimed at bringing the EHR/EMR concept to the attention of government and other players in the health delivery industry.

Methodology

As a concept paper, literature on EHR and the impact on health delivery systems as reported in countries that have implemented such systems, was reviewed. The literature that was reviewed was not restricted to any continent or part of the world and international examples were cited. Our

literature review was argumentative as we argued in favour of EHR. A total of thirty papers were reviewed in this study.

However, our paper suffers from two main limitations. First, being a concept paper on a subject that has not been popular in Zimbabwe and Africa as a whole, the paper was based on studies that were conducted in other countries, notably the United States of America and Britain, which may have different economic and political atmospheres from Zimbabwe. Second, the paper was limited to mere literature review with no practical evidence on Zimbabwe. However, the authors made the paper as detailed as possible, with evidence from other African countries whose economic and political spheres are similar to those of Zimbabwe.

Justification for EHR implementation in Zimbabwe

Healthcare is an information business in the sense that most of what clinicians do is to collect data , for example, by history and physical examination, record data in the patient chart, process data in the form of chosen treatment and transmit information via orders and letters (21). Prior to the advent of IT, medical practitioners were doing all this on paper, resulting in paper medical records.

With due credit given to traditional paper health records, the movement towards EHR is inevitable. Paper health records have been in existence since the seventeenth century (22). Since then, they have gone through a number of changes, including their contents and filing procedures. This was in response to the changes in the medical fraternity. By the 1950s, health records had developed into complicated documents (23), and this is true for the present as health records have become containers of detailed patients' information, as well as the healthcare providers to those patients. Paper records have stood the test of time and they are still characteristic of many healthcare institutions around the world, including both developed and developing countries. Today, there are many functions that are associated with patient health records. Not only is the record used to document patient care, but the record is also used for financial and legal information, research and quality improvements (24).

However, despite them having been tried and tested, paper records are littered with tremendous disadvantages and this has resulted in the emergence of EHR which counter most problems of traditional paper records. Given the fragmented nature of healthcare, the large volume of transactions in the system, the need to integrate new scientific evidence into practice, and other

complex information management activities, the limitations of paper-based information management are intuitively apparent (25).

In the beginning, there was only hand written charts which were time consuming and tedious (26). Illegible handwritten charts not only took a lot of time to undertake and interpret but also more serious problems such as errors in diagnoses, treatment, and billing (27).

Some of the shortcomings of paper-based systems resulted in consumers have poor access to information about costs or quality to make informed decisions about their care (28). Delayed or missing paperwork adds time to patient hospital stays and can lead to unnecessary or duplicate clinical tests. (29). Physicians and nurses spend time away from patients attending to a great deal of paper work (30). An EHR can decrease charting time and charting errors, therefore increasing the productivity of healthcare workers and decreasing medical errors due to illegible notes (31).

Paper records, with their shortcomings, may no longer be viable for a country such as Zimbabwe, which aims at revitalising the healthcare delivery system. In Zimbabwe, the public health delivery system is organised into a hierarchical system of four tiers from least specialised to the most specialised (32). These are Level 1, consisting of primary healthcare (clinics or rural health centres and village health workers), Level 2 consisting District or Mission Hospitals, Level 3 consisting of Provincial Hospitals and Level 4 consisting of Central Hospitals (33). Adding to the complexity, most patients are not attended to by a single physician or one organisation, but a collective process that includes nurses, consulting specialists, diagnostic technicians, and administrative staff (34). Given the arrangement of the healthcare delivery system in the country, which consists of a combination of primary and secondary healthcare systems, all playing a significant role in the administration of patients, completeness and availability of health information to health physicians, nurses and governments is indispensable.

Most medical records are still stored on paper, which means that they cannot be used to coordinate care, routinely measure quality, or reduce medical errors (35). Just like any other recordkeeping, moving patients' records from paper and physical filing systems to computers and their super storage capabilities creates great efficiencies for patients and their providers, as well as health payment systems (36). In light of this fact, health records in paper form may be found to be inadequate to support healthcare facilities in a country whose aim is to revitalise the healthcare delivery system.

Thus, currently the paper record represents massive fragmentation of clinical health information and this does not only lead to increased costs of health information management, but fragmentation leads to even greater costs due to the adverse effects on current and future patient care (37,38, 39,40). For example, in the United States of America, large practices have transcription costs alone reaching more than $US 1 million a year (41). The adoption of interoperable EMR systems could produce efficiency and safety savings of $142-$371 billion (42). Indeed this is indisputable good news, and Zimbabwe can reap the same benefits by implementing such systems. We argue that revitalisation programmes and strategies for a country should be economical.

Zimbabwe is a developing country, and is still creeping from an economic hardship of the last decade. In light of this, the government and other healthcare stakeholders need the health information management strategies that will turn around the country's economic strategies in a cost effective manner. Given the cost effectiveness of EHR as compared to the current traditional paper records in most hospitals in Zimbabwe, we argue that rolling out EHR systems is the best option for the government in an effort to revitalise the health delivery system of the country. EHR capabilities will be essential for physician practices to effectively collect, access and share all information for patient care, capture performance data and lay the foundation for transforming the way care is delivered (43).

ICTs present great opportunities to the healthcare industry in Zimbabwe as EHR allow the physically fragmented healthcare facilities to access, share and improve health information through EHR management systems. Times are rapidly changing and information technology is more widely available in resource-poor areas and it is allowing health advocates to tackle difficult challenges such as managing HIV/AIDS and drug-resistant tuberculosis (44).

In an EHR environment, information such as blood type, prescribed drugs, medical conditions and other aspects of our medical history can be accounted for much more quickly (45). Revitalisation of the health delivery system requires that medical practitioners gain rapid, but authorised access not only to medical records of their patients, but to health information for the whole nation. EHR systems can go a long way in facilitating this. Connection to national diseases registries allows practices to compare their performance with that of others (46).

Mobile populations make it difficult to transfer medical records to the point of care (47). Rolling out EHR in Zimbabwe will go a long way in also putting the country on an international platform where our healthcare practitioners can easily share information with patients who are mobile, including those across borders. EMR are increasingly being deployed in countries across the globe (48) and this enables critical real-time information services that empower both patients and healthcare workers (49). Access to good care becomes easier and safer when records can easily be shared for individual patients (50). Further, electronic messages offer a low-cost, efficient means of distributing reminders to inquiries on a patient (51).

In a country such as Zimbabwe whose health delivery system is also characterised by primary healthcare, in rural areas where most of the population resides, EHR may offer unprecedented benefits. This means that healthcare givers need robust health information management systems that have special alert features to indicate to healthcare givers, the areas that need rapid attention. No doubt, we argue, EHR are a way to go by if the health delivery system in Zimbabwe is to be revitalised. Thus, in what may prove to be a transformative innovation, remote monitoring systems can transmit vital signs and other patient biodata directly from their homes to their providers, allowing nurse case managers to respond quickly to incipient problems (52). The following table illustrates the benefits that users of EHR perceived (53).

Table 1: Perceived benefits of EHR

Benefit to the practice Mean rating
Improved access to medical record information 4.6 Improved workflow 4.49 Improved patient communications 4.28 Improved accuracy for coding evaluation and management procedures 4.28
Improved drug refill capabilities 4.21 Reduced medication errors 4.19

Improved charge capture 4.16 Improved clinical decisions 4.15
Improved claim submission process 4.13 Reduced medical errors 3.96 Reduced medical records storage costs 3.92
Reduced transcription costs 3.92 Reduced medical records transcription costs 3.64 Improved physician recruitment 3.31

Based on a five-point scale ranging from 1 (no value) to 5 (very important value

Lessons for Zimbabwe from other countries: a review of selected case studies

Studies on the adoption of EMR and PHR in developing countries are scarce yet these technologies present many benefits that can improve healthcare management and open these counties up to information and advancement of their healthcare industry (54). Just a few years ago, the use of EMR in resource-poor, developing nations was experimental as few organisations believed that using EMRs was realistic in these regions and fewer still had deployed such systems (55). However, adequate literature exists about the implementation of EHR that support local care and provide sorely needed support for investigators and care programmes in low-income countries (56). Successful EMR projects are now operating in such diverse locations such as Zambia, Peru, Rwanda, Kenya and Malawi (57). In Tanzania and Uganda, OpenMRS were successfully installed and used at six sites (58).

A study that was done at the central Utah Clinic's health records department indicated that EHR dramatically increased efficiency (59). We did a study in our records room which showed that filing

electronically is 80% more efficient than filing manually, and we have seen proof of that on a daily basis, noted Jamie R. Steck, Director of IT, Central Utah Clinic (60). Another study that was conducted in Massachusetts to understand the adoption of basic and advanced EHR capabilities. A survey of ambulatory physicians in the state formed part of the survey (61). The study involved 18 282 Massachusetts physicians contacted through mail and directed to a web-based survey (62). With a response rate of 3%, the study found that:

- Basic EHR capabilities provide physicians with better access to information at the point of care, greatly improving the capability to support clinical decision making;
- Roughly 36% of respondents use all basic EHR capabilities for at least some of their patients;
- Overall 45% of respondents reported that they at least have access to all basic EHR capabilities (63).

Another study was conducted in the USA with the aim of assessing physicians' adoption of outpatient EHR, their satisfaction with such systems, the perceived effect of systems on the quality of care, and the perceived barriers to adoption (64). The study surveyed 2758 physicians (65) in which the following results were obtained:

- Physicians reported positive effects of these systems on several dimensions of quality of care and high levels of satisfaction;
- Financial barriers were viewed as having the greatest effect on decisions about the adoption of EHR (66)

The study then concluded that physicians who use EHR believed that such systems improved the quality of care and were generally satisfied with the systems (67).

In Cameroon, a study on the implementation of EHR was also conducted and concluded that strengthening the medical record in general, and the EHR in particular, could contribute to its position as a valuable source of information for healthcare delivery, public health and policy making (68). In Brazil, an open source EHR care was implemented on a massive scale in 2011, notably in Sao Paulo as evidence grows that EHR systems can improve health care while cutting costs(69). The system has 14 million registered patients and stores data from 702 health facilities annually (70). Without adding any new resources, health officials say that they have noted a 30% increase in patient visits and 50% increase in patient satisfaction (71).

In the United Kingdom, the Summary Care Record (SCR) was launched in 2011 (72). The system contains a summary of health information populated from the electronic records of general practitioners (GPs), with patients' current medications, their known adverse reactions, and their known allergies and the system was set up to assist patients when they seek care during emergency (73). In the United States of America, the Massachusetts eHealth Collaborative and the New York City Primary Care Information Project are other examples of EHR (74).

In light of the case studies given above, EHR offer tangible benefits that a country on a mission to revitalise the health delivery system such as Zimbabwe may consider investing in. Perhaps this paper, as a mere literature review, may not be able to convince the health industry on the irresistible benefits that IT offers in the form of EHR. We recommend that the health industry should conduct studies on the potential benefits of EHR and their tangible benefits to a country such as Zimbabwe.

The status of EHR in Zimbabwe

Scanty literature exists on efforts to invest in EHR in Zimbabwe. The information available also revealed that very little has been done by the country to implement fully fledged EHR systems in the health industry. The healthcare industry lags behind others in the use of technologies that promote high quality service and efficient organisational processes (75). Public hospitals are still characterised by traditional paper records throughout the country. Where electronic systems for the management of health records have been implemented, these are not good enough to be considered EHR that can transform the country's health delivery facility.

IT has been used in the country to manage the HIV/AIDS information. In 2011, the National Aids Council announced the unveiling of a new ARV Electronic Card system that help people living with HIV and AIDS access medication anywhere in the country (76). The system is intended to help monitor drug distribution and to curb abuse (77).The electronic card system is also meant to help people living with HIV and AIDS access medication anywhere in the country (78).

Despite the health industry in Zimbabwe having applied IT for the management of health health information, no studies have been done in the country to determine potential benefits of EHR systems. Thus, while EHRs hold great promise, few studies have been conducted to measure the actual impact of using them to improve the quality, access or affordability of healthcare, particularly in the developing countries (79). Due to a lack of standards for interoperability of such

systems, health information contained in such systems remain inaccessible to other physicians who may be rendering medical care to the same patients.

It is increasingly clear that a lengthy, uneven adoption of non-standardised, non-interoperable EHR systems will only delay the chance to move closer to a transformed healthcare system (80). This results in parallel paper electronic records and this limits the benefits that can be derived from fully implemented EHR. The government and other players should intensify the application of IT for patient administration practice.

Stages required to implement effective EHR systems

Successful EHR/EMR implementation requires that physicians and all other groups who contribute or access the system participate (81). Computer competency and internet accessibility are necessary to facilitate information retrieval and online communication (82). Training for computer competency goes beyond turning a computer on and off; it includes understanding how to navigate the web and complete simple functions such as searching for information, saving information, and sending e-mail (83). EHR implementation also requires full cooperation from all stakeholders, technological/ICT infrastructure, costs and political will.

Challenges of implementing EHR in Zimbabwe: experiences of other countries

Since an EHR is a fairly new concept, there are barriers and obstacles in the implementation of EHR strategies (84). Whilst we urge Zimbabwe to join the band wagon and conduct quantitative studies on potential benefits of EHR in its context, we hint that the country should be wary of possible challenges. The following challenges may be expected.

Financial challenges

Financial constraints have been cited as the main barrier to adoption of EHR (85, 86). For example, a survey of nearly 3000 hospitals in the United States of America showed that less than 2 percent use comprehensive EHR and about 8 percent use a basic EHR in at least one care unit that includes physician or nurse notes bad financial constraints were the major barrier (87). Zimbabwe, given the limited financial base may face such challenges as well. However, one can say that other countries which reported financial constraints as the major barrier towards the effective utilisation of EHR systems are better off than a country which has not publicly declared and enacted enabling legislation to support implementation of EHR. Zimbabwe finds itself lacking public interest to implement and support EHR systems.

Inertia from physicians and health information management professionals

Changing from traditional paper records to EHR may pose problems for physicians and medical records practitioners. Physicians may argue that they lose time focusing on computers in an EHR environment. Information management professionals in the health sector may also resist such initiatives as they may feel that their jobs are at risk. However, it is worth noting that change is inevitable, and the challenge of inertia from all concerned stakeholders are not insurmountable. Thus, if Zimbabwe is revitalising its health industry, EHR, whose benefits are luring as discussed in this paper, efforts can be made to deal with inertia from physicians and health information management professionals. Because we do not have case studies of EHR implementation in Zimbabwe, owing to limited efforts by the country's health industry to implement such systems, we cannot tell how physicians and health information management practitioners in the Zimbabwean situation would react to the implementation of EHR in hospitals. If Zimbabwe is to rollout EHR systems, it has to be prepared to deal with these possible challenges.

Limited ICT infrastructure in Zimbabwe

Despite the country having a brilliant ICT strategic plan for the period 2010-2014 (88), it can be noted that implementation of the strategic plan has not been robustly implemented. This may pose serious challenges and barriers to large scale implementation of effective EHR systems. However, we consider the determination to improve the state of ICT as outlined in the strategic plan of the Ministry of Information Technology a firm foundation for the implementation of EHR. The health industry may take advantage of this positive development in the ICT industry to implement EHR. Coupled with this is the problem of interoperability of EHR standards.

Literature on EHR implementation and adoption in other countries indicated that lack of interoperable standards for EHR systems were one of the challenges that hindered their wide spread adoption. Given limited progress on the implementation of the 2010-2014 strategic plan on IT, the country needs to be wary of the need for interoperable standards that will support effective EHR in order to reap maximum benefits. In order for an EHR to be shared, not only must there be a standard language developed, but a unique health identifier must also be developed (89).

Incessant power cuts

Effective EHR depend on constant power supplies. Zimbabwe is characterised by perennial power cuts and this can be a barrier to the implementation of such systems. If an EHR is the way to

revitalise the health industry, the government needs to invest in dependable electricity supplies. This includes the rural electrification programme so as to support EHR in the remote areas. An effective health delivery system that is underpinned by EHR requires that health practitioners access information from all parts of the country, including the rural areas where the largest population resides. This requires dependable electricity supplies so that databases can be accessed by patients, governments and physicians for the betterment of the health delivery system.

Health information legislation, privacy and confidentiality issues

Health information legislation in Zimbabwe is vague and weak. This is not a challenge for Zimbabwe only, but countries such as the United States of America as well find themselves in a similar predicament despite the Health Insurance Portability and Accountability Act (HIPAA). For example, it is reported that in the United States of America, policy makers are pushing initiatives to bring health care system yet national efforts to advance health IT have not adequately addressed privacy (90). If Zimbabwe is to adopt EHR systems and reap maximum benefits, the government should be wary of the pitfalls of weak legislative infrastructure that other countries that invested in EHR systems have fallen victims.

EHR yield maximum benefits when supported by adequate legislation that ensures patient privacy and confidentiality. This is particularly important for a country like Zimbabwe whose legislation is not clear on privacy on health records management. In EHR environments, tens of thousands of health records may be accessed or disclosed through a single breach (91). Building privacy and security protections into health information technology systems will bolster trust in such systems and promote their adoption (92).

Conclusion and recommendations for Zimbabwe

Based on the literature reviewed on EHR, it can be concluded that Zimbabwe has not done a lot regarding the implementation of EHRs. Achieving more widespread adoption of EHR is a key component of health reform (93). The grounds of the finding leads us to argue that the country has already lost the benefits that ICTs offer to the health industry. We therefore recommend that players in the healthcare industry work together and seriously consider the vast benefits that may accrue in the industry if EHR were to be fully implemented in Zimbabwe. Chief among our recommendations is that the Zimbabwean government should consider and give due attention to the implementation of EHR as part of the efforts to revitalise the health delivery system of the country.

EHR offer unprecedented benefits that could see the country transform the healthcare facilities for patients and the nation as a whole. Chief among the expected benefits of EHR are cost-effectiveness, efficiency of the medical practice, increased patient safety. We therefore urge the government of Zimbabwe to invest in EHR systems as part of the healthcare revitalisation programme.

Although there has been scanty literature on the subject matter on the African continent, the few studies conducted revealed that the benefits of EHR have a potential of transforming health delivery systems of a nation. In the midst of financial constraints for Zimbabwe as one of the developing countries, open source EHR systems may be employed with pleasing results. The country may roll out EHR programmes, starting off with a few healthcare institutions that can be used as case and pilot studies and pilot studies whose results would determine the actual benefits of such systems in Zimbabwe. There must be more involvement by the government and the private sector (94). On this note, a call is made to stakeholder to set the ball rolling for EHR. An enabling legislation is indispensable to such projects and the government of Zimbabwe needs to create legislation on which EHR/EMR will hinge.

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Impact of a Preventive Maintenance Program for HVAC Systems in Hospitals: A Case Study of Kitwe Central Hospital

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Abstract
The purpose of the research was to evaluate the implementation of a preventive maintenance system in the hospital's heating, ventilation and air-conditioning (HVAC) systems. The run-to-failure maintenance strategy practiced on the HVAC system at Kitwe Central Hospital affected the quality of health operations. The researchers set objectives focusing on minimizing equipment downtime and lowering utility costs. Identification of the types of HVAC equipment at the hospital was done followed by the development of an inventory list. The Mean Time Between Failures (MTBF) of the equipment was then established together with the lead times of the inventory items. The design of a replacement program based on the gathered data was developed. The benefits of the research came double folded; the reliability of the HVAC equipment increased and high utility costs which were incurred due to the frequent breakdowns and poor utilization of machines reduced.

Keywords: impact, preventive maintenance, HVAC systems, health operations.

INTRODUCTION

Indoor air quality is an important determinant of population health and well being hence the support of the medical function and the assurance of occupants' health and comfort cannot be complete without a reliable HVAC system. In a hospital, the HVAC system goes beyond providing comfort and ventilation, to being an essential tool for the control of infection, removal of noxious odors, dilution and expelling of contaminants, and establishment of special environmental conditions conducive to medical procedures and patients treating, (Guyer, J.P., 2009).

This research paper therefore, focused on promoting good health in a hospital by implementing a preventive maintenance program on HVAC systems with Kitwe Central Hospital, a case study. The major HVAC equipment at hospital are; the boiler, cold room units, extraction fans, dehumidifiers

and domestic fans. The maintenance of the equipment is done on a run to failure strategy. More so, the workers in the maintenance department have to source the spare parts for the repairs only after a break down has occurred. This results in prolonged equipment downtime.

Implementing a time-based maintenance strategy such as preventive maintenance will favor hospital's operations. With preventive maintenance programs, regular inspections are mandatory to cater for the limits of design capacity of the equipment otherwise delaying preventive maintenance may increase the probability of equipment failure, (Hua, L., 2010). The best insurance against HVAC failure and cost containment is equipment has been known to be preventive maintenance (Piper J., 2009).

Research shows that there have been problems in implementing maintenance systems for HVAC systems and several approaches have already been tried by various institutions. . In spite of years of studies, demonstration programs, and published information to the contrary, most facilities in organizations still operate in a reactive mode. The most common reasons cited for this is the lack of sufficient resources (Piper J, 2009).

The approach to maintenance with respect to HVAC systems in this study was based on designing a preventive maintenance program for the maintenance department focusing on the critical HVAC equipment for Kitwe Central Hospital.

OBJECTIVES

The main objectives of the investigation were to:

- Minimize equipment downtime thereby increasing their reliability.
- Reduce utility costs.
- Ensure well-being occupants of the building.

METHODS

To achieve success in this study, it was imperative that information was obtained from reliable sources. Strategies on how to obtain this information included the following:

Primary Data

Primary data is very critical in a research, (Wilcox, A.B, et al, 2012). Initial familiarization with HVAC systems at the hospital was carried out focusing on the systems of maintenance used, staff

skills, and time scheduled for maintenance. A survey was done on resources and equipment available.

Interviews

The interviews were conducted with the engineering maintenance supervisor. These interviews were conducted to get information yielded highest cooperation and lowest refusal rates, (Owens L.K., 2005), such as on pieces of equipment and machines that the hospital has, frequency of their breakdowns and lead-time of spare parts.

Direct Observations

This assisted in obtaining information about the physical activities and taking note of the events as they occurred.

Secondary Data

The other relevant information concerning heating, ventilation and air-conditioning systems and preventive maintenance was obtained from the records kept at the hospitals' maintenance department, which concerns the number of equipment the hospital has (asset register), the number of breakdowns of each piece of equipment considering the critical components that fail.

RESULTS

The HVAC system at Kitwe Central Hospital consists of a sizable number of equipment that work together to provide the hospital heating, ventilation and air-conditioning requirements.

Hospital's HVAC System Inventory

The asset inventory equipment is as shown in Table 1 below.

Table 1: HVAC System Inventory

Ref	Item	Quantity	Application
1	Electrical Boiler	1	Heating rooms, kitchen, laundry and the theatre
2	Cold Room unit	3	Storage of corpses
3	Exaction Fan	19	Extraction of air from rooms, theatre and other departments
4	Domestic Fan	20	Air-conditioning rooms, wards and offices.

Parts' Listing

Each piece of the equipment listed in Table 1 is made up of various components or parts with different modes of failures as well as mean time to failure.

Criticality Analysis

The failure of some components may be more critical to the overall performance of the hospital's HVAC system than that of others. Focus was given only to the parts that were deemed to be critical to the functioning of the hospital's HVAC system.

Parts coding nomenclature

A detailed listing of the parts followed with assigned codes for ease of identification of the components and this is presented in Table 2.

The code is based on the following:

- It is made up of six characters that distinguish each unique part.
- The first two characters are for family identification, indicating the use of the part on the equipment.

EB- Electrical Boiler

EF- Extraction Fan

AC- Air-Conditioner

CR-Cold Room unit

DF- Domestic Fan

- The next two characters are numbers from 01 to 09 assigned within each family, e.g. EB01 to EB09, DF01 to DF09 etc.
- The fifth character is a letter representing the functioning of the part as follows;

  M- Mechanical

  E- Electrical

  T- Other part
- The sixth and final character was a letter indicting the physical nature of the part as follows;

  M- Metal

  R- Rubber

  P- Plastic

  O- Other

Table.2: list of parts of equipment

ITEM	PART NUMBER	DESCRIPTION	QUANTITY/UNIT	TOTAL PARTS	MTTF(WEEKS)	FAILURE MODE
ELECTRICAL BOILER	EB01EM	Mild steel electrode	3	3	26	Scaling
	EB02MM	Sleeves	9	9	52	Loss of insulation due to heat
	EB03ER	Blow down hose	2	2	104	Crack or puncture
	EB04EM	Control transformer	1	1	104	Insulation resistance
COLD ROOM	CR01EM	Compressor motor 2HP, 380	1	3	74	Burnt winding or ceased motor
	CR02MM	Compressor piston	2	6	156	Swaps/breaks due to lack of lubrication
	CR03MM	Compressor shaft	1	3	156	Breaks due to tear and wear
	CR04MR	Compressor seal	2	6	104	Wears out
	CR05M0	Compressor gasket	1	3	74	Burns out due to excessive heat
	CR06MM	Compressor valve	2	6	104	Wears out
	CR07EO	contractor valve 220VAC, 30V	2	6	116	Fails to change
	CR08EM	Contractor fan motor 0.5kw	1	3	52	Motor burn out or cease due to bearing
	CR09MM	Condenser copper line embedded fins	1	3	156	Wear and tear, corrosion
	CR10TO	Refrigerant R134A	1	3	156	Leak out from seals
	CR11EM	Evaporator motor 1kw 38VAC	2	6	74	
	CR12MT	Expansion valve 2"	1	3	156	Fails to hold(due to dirty orifice)
EXRACTION FAN	EF01EM	Electric motor 0.55kw	1	19	104	Motor burn out
	EF02EM	Ball bearing	2	38	39	Ceases due to heat up or dryness
	EF03MP	Blade	1	19	52	wear and tear
DOMESTIC	DF01EM	Electric motor 0.01kw	1	19	52	motor burn out

Table 3 gives details on the replacement job and the sourcing lead times involved for each item.

Table.3: Lead times and Job Replacement detail

ITEM	NO. OF ITEMS IN SYSTEM	COMPONENTS	TIME TO REPLACE (HRS.)	TOTAL HRS REQUIRED TO REPLACE PART ON ALL UNITS	EQUIV. DAYS FOR AVAILABLE LABOUR	TIME TO SOURCE (WKS)	TASK TO BE DONE BY
ELECTRICAL BOILER	1	EB01EM	8	8	1	8	Electrician
	1	EB02MM	2	2	1	8	Fitter
	1	EB03ER	1	1	1	1	Fitter
	1	EB04EM	8	8	1	1	Electrician
COLD ROOM	3	CR01EM	8	24	3	4	electrician
	3	CR02MM	2	6	1	2	Fitter
	3	CR03MM	1	3	1	1	fitter
	3	CR04MR	1	3	1	1	fitter
	3	CR05M0	1	3	1	1	fitter
	3	CR06MM	1	3	1	4	fitter
	3	CR07EO	2	6	1	1	fitter
	3	CR08EM	4	12	1	1	electrician
	3	CR09MM	3	9	2	3	electrician
	3	CR10TO	1	3	1	2	fitter
	3	CR11EM	6	18	2	1	electrician
	3	CR12MT	1	3	1	1	fitter
EXRACTION FAN	19	EF01EM	1	19	3	4	fitter
	19	EF02EM	2	38	5	1	fitter
	19	EF03MP	1	19	3	4	fitter
DOMESTIC FAN	20	DF01EM	4	80	5	3	electrician
	20	DF02MM	1	20	3	1	fitter

Assumptions made:

- Each technician works 8 hours/day, 5 days/ week
- There are 2 electrical artisans and one mechanical artisan available for jobs
- A job that will take 8 hours to complete and a task that will take only 3 hours will both be considered as requiring one day.

Electrical Boiler PM Schedule

The electrical boiler's maintenance was considered critical hence its maintenance schedule was drawn and was as presented in Table 4.

Table.4: PM schedule for electrical boiler

MONTH	WEEK	INITIATE SOURCING	ARRIVAL OF PART	TOTAL TIME TO REPLACE	DOWN FOR MAINTENANCE	TASK TO BE DONE BY	PREDETERMINED BREAKDOWN
Apr	16	electrode x 3 EB01EM					
Dec	24		electrode x 3 EB01EM				
				6	electrode x 3 EB01EM Replace Electrodes	electician	
Feb	26						EB01EM x3
Jun	42	EB02MMx 9					
Feb	50		EB02MMx 9				
Mar	51			18	EB02MMx 9 SLEEVES	Fitter x 1	
Apr	52						EB02MMx 9
Mar	101	EB03MRx 2 blow down hose					
Apr	102		EB03MRx 2				
May	103			2	EB03MR x 2 replacement	fitter x 1	
Jun	104						EB03MR x 2

Utility Costs Reduction

Energy Savings

The annual power bill for Kitwe central hospital was estimated to be K 14,000,000. It was established that electrical motors (biggest load) at the hospital accounted for 80% of the total power bill whilst operating at 90% of their full-load ratings. With the implementation of a preventive maintenance program, this would reduce to approximately 75% full load current after replacement of parts such as bearings.

Illustration of the Energy Savings

Annual power bill is **K14, 000, 000**

Cost attributable to electric motors

80% X K14, 000, 000 = **K11, 200,000**

This is at 90% power rating.

Power Bill with Preventive Maintenance

At 75% of rating cost would be:

75% X K 11200000/90% = **K 9,333, 333**

Calculation of Energy Saving

K11, 200,000 – K 9,333,000 = **K 1, 866,667**

Percentage of Energy Saving

1866667/11200000 = 17%

Implementing Preventive Maintenance would result in energy savingsof **17%.**

Labour Savings

With a preventive maintenance program in place, the hospital may subcontract workers on the critical maintenance work. This would lead to a considerable amount of savings in labor. A comparison of labour Costs between reactive and preventive maintenance were compared.

Labour costs with Breakdown Maintenance

The labor costs were calculated over a three-year period as this concurred with the Preventive maintenance schedule's cycle.

About 156 weeks is equivalent to 780 days (if 1 week = 5 days)

Each worker works for 8 hours/day

Each worker is paid K 3,700/hour

Each foreman is paid K4,500/hour

There are four (4) workers

There are two (2) foremen.

For 780 days, which is a period of 3 years, cost will be:

780 X [(4X 3700X 8) + (2 X 4500 X 8)] = **K 148, 512, 000**

It is assumed that the entire work-force was present on any day.

Labour Costs with Preventive Maintenance

This was calculated considering the number of hours when replacement of the critical components is needed in the three-year period, and if the hospital decides to subcontract the workforce.

The total work hours required will be 113hours

Assuming a contractor's workforce of 1 foreman and three artisans, the hourly cost is

3 X K , + K4,500 = K 15, 600

Therefore, total cost for 113 hours

113 X K 15,600 = **K 1, 762, 800**

If we further assume that the contractor puts a mark-up of 30% on all labor charges, then

Total cost = 130% X K 1,762,800

= K 2, 291, 640

Labour Savings

The labor savings are;

K 148, 512, 000 – K 2, 291, 640

K 146,220,360

Greater comfort for the building's occupants.

Though it may be difficult to quantify this in figures, from the interviews conducted, the hospital occupants like the nurses and other workers when interviewed, their answers were all directed towards having a system in place that prevents HVAC systems breakdown and therefore improving system availability.

DISCUSSIONS

Reliable HVAC systems are critical in creating a comfortable indoor environment and it reduces the incidence of hospital acquired infections. Ventilation needs to meet specific requirements of hospital units, patient rooms and common areas. According to research, proper ventilation is critical since one-third of all infection threats are airborne (www.mcdmag.com).

Temperature affects patient, staff and visitor comfort. Maintaining the right temperatures can help create an indoor environment that promotes healing and prevents pathogens to grow and spread. To achieve this in HVAC systems, there is need for a maintenance program or schedule which can be used by the hospital. Preventive maintenance was the best strategy as observed in this research since breakdowns are prevented thereby reducing equipment downtime. To improve the comfort of hospital occupants, scheduled cleaning of the critical equipment will improve the running times.

This schedule or program was designed considering that the cost of implementing a preventive program is costly and thus the research focused only on equipment which was deemed critical to the operation of the hospital. From the data that was obtained from the interviews and familiarization with the HVAC systems and maintenance department, it was possible to design a simple but practical preventive maintenance program for this hospital. Focusing on the utility cost reduction, it was possible to reduce the cost of energy if critical components such as motors were operating efficiently.

Instead of waiting for problems to arise, hospitals can take a proactive approach to air conditioner maintenance and reduce energy costs. Scheduled HVAC maintenance reduces the possibility of service disruption, indoor air contamination and costly repairs.

Considering the fact that critical components for the hospital HVAC system are known, the lead times for spare parts, personnel and the knowledge of the failure history being available, it becomes possible to build these factors in the maintenance department operating costs. Regular HVAC service can become a manageable fixed cost, necessary to keep the facility running efficiently and therefore reduce the costs incurred as a result of breakdown maintenance demonstrated in this research.

HVAC systems that are not performing at peak efficiency can seriously affect a hospital's environment of care by allowing indoor air quality to deteriorate. For example, a faulty dehumidification system could create a humid environment where pathogens can grow and result in increasing the spread of infections. Conducting an HVAC critical system audit, can help hospital facility managers identify potential reliability and performance problems, reduce the chance of unplanned system failure and identify energy saving opportunities (www.mcdmag.com).

The system designed for Kitwe Central Hospital focused only on the critical equipment and also it was more of a manual program which can be improved upon by programming the system and adding more HVAC equipment as the hospital is expanding.

CONCLUSION

The designed preventive maintenance program is a good start for a hospital that does not have the money to invest in a computerized system. This program may take some time but it is a cheap way to start implementing preventive maintenance to HVAC systems. Implementing preventive maintenance will certainly improve the comfort of the buildings' occupants accompanied by an increase in the availability of the equipment to perform its operation.

RECOMMENDATIONS

- The researcher recommends that the system be converted to a computerized version that can be able to incorporate more HVAC equipment for the hospital.

- The maintenance staffs need regular refresher training in order to be in full control of the system

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The extent to which Mutare Teachers' College is a health promoting college.

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INTRODUCTION

Health promotion (HP) is defined in a number of similar ways. It is defined as " multidimensional phenomenon with bio psychosocial, spiritual, environmental and cultural dimension- in a positive model of health, emphasis is placed on strengths, resilience, resources, potentials and capabilities rather than on existing pathology"(1 p.16). HP is a combination of educational and environmental support for actions and conditions of living conducive to health (2 , 3). It is the process of enabling people to increase control over their health and its determinants and thereby improve their health (4 , 5). HP works to prevent the development of personal and campus population health problems, while enhancing individual, group and institutional health safety. In Higher Education, HP emphasizes creating supportive environments for health (6). HP also seeks to effect changes in the health behaviours of individuals (7). It provides an alternative to the medicalised notion of health (8- 12). HP being so broad, cannot be the responsibility one group of actors within the college, but should be understood as a shared responsibility.

The concept of a healthy college has emerged and is continuing to develop at local, regional and national level (2, 3). As self-reliant as many of them may seem, some students are still emerging adults susceptible to all sorts of risky behaviours (13). College students comprise a vulnerable high risk population. Some students find life in college a very big contrast to school. Transition to college life is known to be an exciting as well as stressful time for adolescents and young adults. They are forced to adapt to significant changes (14, 15). Some of them live away from their families and support systems for the first time. They may not be equipped to resist peer pressure.

Studies have shown that adjustable unhealthy behaviours exist among college students (16). Some other studies revealed that college students do not constantly participate in health-promoting behaviours (17, 18). In higher education settings student counselling and health services reported a progressive increase in the number of students presenting to them. It is believed that mental health problems experienced by students were becoming more severe (19). With regard to students'

mental health (20 p. 22) suggested factors that should be taken into account when seeking to promote mental health in universities. The implication here is that coordinated effort from different care givers is needed to address students' health concerns. It was found that students need assistance on how to adjust to college life (21). It has been reported that university- based health promotion can potentially enhance the contribution of universities and colleges to improving the health of populations and to adding value in a number of ways (21). Colleges have the international capacities, the skills, the authority and credibility for developing into model health- promoting settings (22). A health promoting college supports healthy personal and social development, enabling students to discover and explore their potential, facilitating them making healthy choices and encouraging them to explore and experiment safety (23). HP reduces campus and community health risky factors (5). A healthy college understands the importance of investing in the health and welfare of its students to maximise achievement through providing an environment conducive to learning. HP in higher education advocates for health-supporting environments guided by cultural inclusion, respect, equity and equality (24). Overall the purpose of health promotion in higher education is to support student success There is therefore a strong need for health promotion in the college setting.

Internationally, a number of studies have examined the effectiveness of approaches to promoting health in colleges. A study was conducted in Germany on the contribution of health discussion groups to health promotion ((25). One key evaluation of a health promoting university approach comes from China ((26), where it was reported that the approach brought about positive changes in students' health, knowledge and behaviour. In USA some of the studies focused on specific health issues such as alcohol use (27 -30), use of tobacco (31 32), mental health (33 - 35), infectious diseases(36) and sexual health (37). Other investigations have focused on multiple risk behaviours such as physical activity (38), yet others address the health of particular groups such as male students (39) and those with learning disabilities (40). Two other studies reported specifically on the need to improve psychological and mental support for students (41).

The term health promotion emerged in US policy in 1975 as a substitute for the term health Education (1). The notion of HP in Europe has its origins in 1980, when the World Health Organisation (WHO) regional office recognised that health education in isolation from other measures would not necessarily result in radical changes in health and introduced a range of non-educational approaches which were designed 'health promotion'(42).These focused on the social, political and economic determinants of health not amenable to improvement by medical

care(43).Today's HP concept was adopted at the First International Conference on Health Promoting University, held in Ottawa, Canada in November 1986 (20,44 , 45). The concept focuses on around five main action areas: Building Health Public Policy, Create supportive environment, Strengthening Community Actions, Develop Personal Skills and Re- orient Health Services. The concept of health promoting colleges was outlined as early as 1993 in a report 'The Health Promoting College' (46, 47). In 1995 , The University of Central Lancashire became one of the first few universities in Europe to establish a Health Promoting University (HPU) initiative (48). Its concern was with supporting the healthy personal and social development of students. It achieved this by investment in support structures, systems and processes by working in active cooperation with student services to promote well-being (48).

HP is a rather new concept for Sub Saharan Africa (49). In 2001, the WHO regional office for Africa finally recognised the importance of health promotion in addressing the major health problems of the region (45). It was stressed that over the last 20 years there has been a significant acceleration in development of health promotion in Africa (50).

The success of a health promoting college depends on its ability to integrate a commitment to health within the policies and practice of the college (51). The key features of a healthy college should include: the institutional procedures, values and policies; the environment; the curriculum and the staff/student relationship including pastoral support for students (45). HP should include creation of a health-supporting physical and social environment, including promotion of safety, sanitary facilities, green areas, healthy study and living facilities, a trusting and interpersonal caring atmosphere and appropriate help for the handicapped and those with lower economic status (51 - 53). Health promotion is therefore by design a collaborative and collective campus effort (12, 54).
HP initiatives should be guided by accepted theoretical framework and planning models (55). In support (45-47) suggest that the health promoting college approach should be informed by HP theory. Reported information about the research has been therefore limited to assessment of three elements of a health promoting university of the Organisation Model by Baric (56). The three elements are: creating a healthy- working, learning and living environment; increasing the health promotion and health education content of the academic work of students and creating health promoting alliances by outreach into the community. The major health service units which were looked at are: the student support centre, the halls of residence, college clinic, the dining hall, the health and life studies course and the college infrastructure.

OBJECTIVES

The study sought to establish the extent to which Mutare Teachers' College (MTC) is a health promoting college. Specifically the study addressed the following question: To what extent do the health systems/ units at MTC promote sound health for students?

METHODOLOGY

Design

Mixed method approaches were used to collect data. Both quantitative and qualitative designs were used. A survey, an interview and a Focus Group Discussion (FGD) were used. The mixed method approaches were appropriate in this case because they can best capture the complexity of some social issues. They can capture different perspectives, enhancing the ability to represent complexity and multiple levels. Combining different data sets in mixed methods enhances transferability, generalisability and practical significance (57).

Sample

The sample consisted of 66 respondents (6 Student Representative Council (SRC) members, 16 Health Education (HE) peer educators, 20 Environmental Education (EE) peer educators, 5 students with disabilities, 13 other students, 2 members from administration, 2 members from the registrar's office, the college nurse and the head cook in the dining hall). Purposive sampling was used to select all except 13 other students who were selected using simple random sampling.

Instruments

Instruments used were questionnaire, interview guide and FGD guide. There was a questionnaire and an FGD guide for all categories of students and an interview guide for administration representatives, those from the registrar's office, the nurse and the head cook. The interview guide and the FGD guide contained similar open ended questions. The open-ended questions evoked fuller and richer responses (58). The first section of the questionnaire contained demographic information about respondents' sex and category. The questionnaire contained closed ended questions. A five- point Likert-Scale was used to rate descriptive statements as follows: 1. Strongly disagree 2. Disagree 3.Uncertain 4. Agree 5.Strongly agree.

DATA COLLECTION

The researcher personally handed the questionnaires to the different categories of students to administer in the large lecture theatre with the assistance of one staff member. The visually

impaired had the questions dictated to them by the researcher after others had completed and their responses were recorded by the researcher. Those students with low vision had their questionnaires written in large print for easy reading. Respondents from each category were given one and half hours to complete the questionnaires while the researcher was waiting. This ensured that all questionnaires would be completed and returned at the end of the exercise. After completing the questionnaires, dates were set for the different FGDs. The members of administration and those from the registrar's office were booked for interviews which were conducted during their free time. Discussions were facilitated in a way that allowed members to freely air their views, feelings, perceptions and beliefs about health promotion in the college. Responses from interviews and FGDs were captured and recorded for validation of some responses given in the questionnaires.

Data Presentation and Analysis

Data was presented in percentage frequency tables. Data was analysed using percentages, mean responses, standard deviations and analysis of variance (ANOVA). High mean response (3.5-5) indicated that the majority agreed, a mean response of(2.5-3.4) showed that there was no clear cut decision made and a low mean response (1-2.4) indicated that the majority disagreed.

ETHICAL Issues

Permission to conduct the study was granted by the college administration. Verbal consent was obtained from the students and those interviewed. Participants received explanatory information describing the voluntary and confidential nature of the study.

RESULTS

Table 1: Results of Analysis Of Variance (ANOVA)

	F	Crit	p	
1. There is a health policy at college	2.339	F(4;52.0.05) =2.55	0.067	ns
2. There is a health coordinator in the college	1.448	2.55	0.23	ns
3. Students are aware of National Health Policy	1.327	2.55	0.27	ns
4. The college is aware of students' health needs	0.7233	2.54	0.58	n/s
5. The college is inclusive	0.8812	2.54	0.48	n/s
6. The students are equipped with the necessary life skills to survive the challenges of the new college environment	3.680	2.55	0.010	s

7. Accommodation in compass is adequate for all those who wish to be resident students.	2.225	2.55	0.079	n/s
8. Students' hostels have adequate resources.	0.6658	2.54	0.62	n/s
9. Hostel wardens attend to students' needs timeously	1.840	2.56	0.14	n/s
10. There is continuous improvements of to the physical environment of the college to promote health and safety	1.204	2.54	0.32	n/s
11. The college ensures that students' study and academic workloads are reasonable.	2.290	2.54	0.071	n/s
12. The college is working to establish good interpersonal relationships.	1.376	2.54	0.25	n/s
13. The college works with other organizations to promote health of the students	1.782	2.55	0.15	n/s
14. There is a tutorial programme which addresses health issues	0.6466	2.54	0.63	n/s
15. There is guidance and counselling facilities in the college.	0.15	2.54	1.745	n/s
16. The college clinic is open to students every time.	0.5972	2.54	0.67	n/s
17. There is a wide range of drugs offered to students at the clinic	3.563	2.54	0.012	s
18. The students get a balanced diet at the dining hall.	2.592	2.56	0.048	s
19. There is a system that allows students to give feedback on the food and services offered in the dining hall	2.866	2.55	0.032	s
20. Students contribute actively to the health promotion in the college.	3.400	2.54	0.015	s
21. Student own the health promoting activities in the coll.ege	2.307	2.54	0.069	n/s
22. Infrastructure in the college allows for mobility of every student.	0.7705	2.55	0.55	n/s
23. The system in the college work together to promote health of the students	1.573	2.54	0.19	n/s

The analysis of variance was performed to check whether there were significant differences in mean response among the five categories-SRC, HE, EE, Disabled and other students. The computed ANOVA in table 1 revealed that there was no significant difference in mean response among the groups on most items. Significant differences were noted on items: ' students are equipped with the

necessary skills to survive the challenges of the new college environment', 'there is a wide range of drugs offered to students at the college clinic', 'students get a balanced diet at the dining hall', 'there is a system that allows students to give feedback on the food and services offered in the dining hall' and 'students contribute actively to health promotion in the college'.

Table 2: Results of students' responses on health issues

Item	Sex	SD	D	U	A	SA	N/R	mean response	Std dev
1. There is a health policy at college	M	9	16	19	38	16	3	3.4	1.58
	F	4	18	11	50	14	4	3.5	1.08
2. There is a health coordinator in the college	M	3	9	16	50	19	3	3.8	0.98
	F	0	4	21	46	25	4	4.0	0.81
3. Students are aware of National Health Policy	M	6	22	25	41	6	0	3.1	1.04
	F	11	18	29	36	7	0	3.1	1.12
4. The college is aware of students' health needs	M	13	6	19	41	19	3	3.5	1.25
	F	4	11	14	61	11	0	3.4	1.19
5. The college is inclusive	M	3	0	9	22	63	3	4.5	0.9
	F	0	0	14	54	29	4	4.2	0.65
6. The students are equipped with the necessary life skills to survive the challenges of the new college environment	M	0	9	25	41	25	0	3.8	0.91
	F	14	7	4	4	29	4	3.7	1.36

					3				
7. Accommodation in compass is adequate for all those who wish to be resident students.	M	50	34	13	3	0	0	1.7	0.81
	F	29	50	4	14	4	0	2.1	1.1
8. Students' hostels have adequate resources.	M	22	44	6	22	6	0	2.5	1.23
	F	7	50	11	32	0	0	2.7	1
9. Hostel wardens attend to students' needs timeously	M	16	25	22	28	9	0	2.9	1.24
	F	7	25	18	46	4	0	3.2	1.07
10. There is continuous improvements of to the physical environment of the college to promote health and safety	M	0	6	13	50	31	0	3.9	0.83
	F	0	11	7	64	18	0	3.5	1.29
11. The college ensures that students' study and academic workloads are reasonable.	M	16	6	9	53	16	0	3.5	1.29
	F	29	7	29	36	0	0	2.7	1.23
12. The college is working to establish good interpersonal relationships.	M	3	3	22	38	31	3	3.9	0.98
	F	0	0	11	57	32	0	4.2	0.62
13. The college works with other organizations to promote health of the students	M	3	0	13	44	38	3	4.2	0.88
	F	0	0	11	57	29	4	4.2	0.62
14. There is a tutorial programme which addresses health issues	M	0	16	19	34	28	3	3.8	1.05
	F	0	7	7	46	36	4	4.2	0.85

15. There are guidance and counselling facilities in the college.	M	0	3	19	38	38	3	4.1	0.83
	F	0	4	4	61	32	0	4.2	0.69
16. The college clinic is open to students every time.	M	31	44	16	6	0	3	2.0	0.86
	F	46	36	4	11	4	0	1.9	1.14
17. There is a wide range of drugs offered to students at the clinic	M	6	41	25	16	9	3	2.8	1.09

	Sex	SD	D	U	A	SA	N/R	mean response	stdev
18. The students get a balanced diet at the dining hall.	M	19	34	3	31	13	0	2.9	1.39
	F	21	29	4	43	4	0	2.8	1.3
19. There is a system that allows students to give feedback on the food and services offered in the dining hall	M	9	22	3	47	13	6	3.4	1.25
	F	11	36	11	32	11	0	2.9	1.25
20. Students contribute actively to the health promotion in the college.	M	0	38	0	50	9	3	3.3	1.09
	F	14	43	0	36	7	0	2.8	1.27
21. Students own the health promoting activities in the coll.ege	M	7	27	10	50	7	0	3.2	1.13
	F	14	43	11	21	7	4	2.6	1.19
22. Infrastructure in the college allows for mobility of every student.	M	19	19	16	38	6	3	2.9	1.27
	F	4	36	18	29	14	0	3.1	1.16
23. The system in the college work together to promote health of the students	M	7	30	13	33	13	3	3.2	1.22
	F	11	32	11	32	14	0	3.1	1.29
	F	21	36	21	11	11	0	2.6	1.25

Table 2 reveals that generally there were no significant differences in responses by male students and female students. Some differences were noted on items: 'there is a system that allows students to give feedback on the food and services offered in the dining hall', 'students contribute actively to the health promotion in the college' and 'students own the health promoting activities in the college', where more females than males viewed the items negatively.

Highly rated items were: ' the college is inclusive', ' the college is working to establish good interpersonal relationships', 'the college works with other organisations to promote health of students' and ' there are guidance and counselling facilities in the college'. Lowly rated items were: 'accommodation in campus is adequate for all those who wish to be resident students', students' hostels have adequate resources' and 'the college clinic is open to students all the time. There was a significant percentage of response 'uncertain' in the items. Notably, 7/23 of the items had 20% and above of the responses as 'uncertain'.

DISCUSSION

It emerged from the study that students at Mutare Teachers' College view the college as a health promoting college. Although students agreed that there is a health policy in the college and that there is a health coordinator, it became clearer from interviews and FGDs that there is an HIV and AIDS Policy and an HIV and AIDS coordinator. It also emerged that most students were not aware of the National Health Policy. It was also revealed that the college is inclusive. The college caters for the visually impaired, albinos and those with physical disabilities. The study revealed that students are equipped with the necessary life skills to survive in the college. In support it was found that students need assistance on how to adjust to life at college (21). Results from FGDs and interviews revealed that more needs to be done. Equipping students with life skills should be a continuous process and not just done during orientation.

There was dissatisfaction on accommodation in campus and services by wardens. More female students than males rated the services favourable compared to males perhaps because of their being more independent and careful when using the hostels. Students overwhelmingly perceived the college as continuously improving the physical environment to promote health and safety. Results from interviews and FDGs revealed that the college has equipped the college gym with the state of art equipment for students' exercise. In support it was argued that in higher education, emphasis should be on creating supportive environments for health (6). In line with this, health supportive environments for health were advocated for(24). This is also in line with Baric's Organisation Model of creating a healthy-working, learning and living environment. Female students encouraged

for the speed completion of incinerators. Not all infrastructures were perceived to allow mobility of every student. Buildings not allowing mobility were cited as the Vice Principal's and the Principal's offices, the library and some of the computer laboratories.

The college was found to be working to establish good inter personal relationships and to be working with other organisations to promote health of students. Results from interviews and FGDs revealed that the Principal meets the SRC members every week to discuss students' problems and concerns. It was also revealed that there were a lot of organisations that work with the college to promote health of students. Some of the organisations named were: Youth Alive Zimbabwe, FACT Mutare, SAYWHAT, VVOB, PSI and EMA. The finding is in line with one of the elements of Baric's Organisation Model of creating health promoting alliances by outreach into the community. Results from interviews and FGDs revealed that most of the organisations work with peer educators who rarely cascade the information to other college students.

The study also revealed that there is a tutorial programme which addresses health issues. This supports one of the elements of Baric's Organisation Model of increasing the health promotion and health education content of the academic work of students. Results from interviews revealed that guidance and counselling services in the college were inadequate. It was revealed that not many students are keen to access the services. Some of the students were not willing to open up and at times the service providers were not available. For Voluntary Counselling and Testing (VCT), it was suggested that the teams should come regularly to the college to assist students.

Services at the clinic were overall rated unfairly. It emerged from FGDs that students were not satisfied by the number of hours the clinic was open each day including its being closed during the week end. It also emerged from FGDs that it took a very long time for a student to be taken to hospital when seriously ill. There were so many people to be contacted before the patient is taken to hospital. There is no ready vehicle to take students to hospital in case of emergence. The only aspect which was rated fairly at the clinic was condom distribution.

The study revealed that services in the dining hall were rated poorly. Results from FGDs indicated that the neediest area was on breakfast. Although there were systems available for giving feedback on quality and quantity of food, the item "There is a system which allows students to give feedback on the food and services offered in the dining hall" was rated negatively. From interviews and FGDs, it was revealed that there were SRC representatives, wardens on duty and the registrar. The

systems were however said to be ineffective. Since most of those who rated the item negatively were female students, it might be because there are fewer female SRC representatives and most of their complains may be misrepresented.

More than half the male students agreed that students contribute actively to health promotion in colleges and that students own the health promoting activities, whilst less than half the female students agreed. This might be because females have more health needs than males and also that there are more male SRC members and peer educators than females as such females' health needs may not be well presented by males. Contrary to the findings it was argued that health promotion is achieved by investment in support structures, systems and processes by working in active cooperation with student services to promote well-being (48). Results from FGDs revealed that female students were not happy with the current method of disposing sanitary pads. From the discussions it was revealed that actions are provider driven and do not actively involve students.

The study finally revealed that health systems in the college do not work together to promote the health of students. Although all the systems work to promote the health of students, each system does its own activities without consulting the other systems. In other words, actions are useful, but are fragmented and developed independently of each other. Contrary to the findings it was argued that effective HP requires enlisting the support of the many individuals and institutions that have contact with or otherwise affect the lives of students (12). They suggested that HP is by design a collaborative and collective campus effort.

CONCLUSION

The study found out that Mutare Teachers' College is working to promote the health of students. It was revealed that college students are generally positive with the health services offered by the different systems in the college. They however expressed dissatisfaction on areas such as disposal of sanitary pads for female students, operations of the college clinic and guidance and counselling services in the college.

RECOMMENDATIONS

Given the increasing interest in the health and well- being of college students, it is recommended that a health policy be put in place at Mutare Teachers' College to ensure that there is inter-service synergy on health promoting. It is also recommended that HP should be based on assessment of students' health-related interests, concerns and needs. The views of lecturers and non-lecturing staff

should also be considered in future studies. Further research in this area is needed on a larger scale in the country.

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Urinary schistosomiasis: Lack of knowledge could be hampering eradication efforts.

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INTRODUCTION

Schistosomiasis is the second only to malaria as the major cause of morbidity in endemic areas. The WHO estimates that about 700 million people are at risk of infection and about 230 million are infected and 90% are in Africa (WHO, 2012). It is a disease of the tropics and is propagated by poor water and sanitation that is common in impoverished African communities. There are two major types of schistosomiasis, urinary schistosomiasis, caused by Schistosoma haematobium and intestinal schistosomiasis caused by Schistosoma mansoni. Urinary schistosomiasis presents as blood in urine and intestinal presents as eggs in faeces. One becomes infected with schistosomiasis when they come into contact with water infested with infected intermediate snail host.

The disease does not manifest with clear symptoms. Therefore one can live with the diseases all their life if not diagnosed. The repercussions of having schistosomiasis is pronounced in young school-going children particularly the age group 6-16 years, but of late we have noted that even the children under five years are exposed to schistosomiasis in endemic areas. The methods of preventing schistosomiasis include: improved water and sanitations and health education. There is no vaccine available as yet for the disease, and the treatment regimen that has been found to be highly successful is praziquantel. Re- treatment after re-infection has also been found to be effective. Control methods have relied on reducing the number of infections in people and/or eliminating the snails (mullosisciding) that maintains the parasite's life cycle. Control measures can alsoinclude mass drug treatment of entire communities and targeted treatment of school-age children using government recommended de-worming protocols. The objectives of the study were to evaluate the prevalence of schistosomiasis in the study area; to ascertain the knowledge, attitudes and practices of the population to schistosomiasis and to evaluate the effect of anti-helminth treatment to the study population including children under 5 years old.

METHODOLOGY

The study design

The study was a community based longitudinal intervention that involved examination and treatment of the study population at baseline, 6 weeks, 6 months, and 12 months follow up surveys, respectively. The sample size for the study was calculated using the previous prevalence of S. haematobium, 58.7% and malaria, 23.5% observed in Murewa district f2rom previous studies (GoZ, 2000). The following formula was used: n = (z/delta) P(1-P), where n = the sample size required, Z-statistic = 1.96, delta (margin of error) = 0.05 and P = proportion or prevalence of the disease (58.7%, 23.5% respectively). The optimum sample size (n = 373) was estimated. This was adjusted by

30% to n = 485 considering possible loss due to follow up. All children from grades 1 through to 7 and secondary school children were eligible for the study. Children severely sick and those who could not provide stool, urine or blood samples were excluded from the study.

Ethical approval

The Medical Research Council of Zimbabwe gave ethical approval (Mduluza MRCZ/ A/1408; 2008) and the University of Zimbabwe gave institutional approval for the study. In addition, provincial, district medical and education directors, chiefs, councillors and village headmen granted permission. General information regarding the nature of study and objectives was explained to the community and study participants. Feedback and consent was sought at schools and village meetings. Inclusion of children into the study took place after free individual, parental and school authority informed consent. Children joined the study voluntarily and were allowed to drop out at any time they wished without any prejudice.

The study area and population

The study was conducted in the Mashonaland East Province of Zimbabwe (31 o30'E; 17 o45'S) where S. haematobium is endemic. Mashonaland East Province was conveniently chosen for the sudy due to its geographical location characterized by high annual rainfalls, wet soils and malaria endemicity (Zimbabwe National Health Profile, 2002). These conditions are conducive for survival of schistosome species, soil transmitted helminths (STHs) and malaria vector mosquitoes (Midzi et al., 2009). Mashonaland East was also conveniently chosen due to the known high schistosomiasis endemicity in the province (Taylor and Makura, 1985). The study area is characterized by high temperature ranges 20 to 32 oC. The main activity in these villages is

subsistence farming, and human water contact is frequent with at least four contacts per person per week, due to insufficient safe water sources and sanitation facilities (Mutapi et al., 2007). Drinking water is fetched from open wells while bathing and washing is conducted in the main rivers running through the villages. Most families maintain a garden located near the river where water is fetched for watering the crops, further increasing water contact. The schools surveyed were secondary schools and the feeder primary schools; Magaya and Chitate Schools in Murewa were all in close proximity to rivers. Mass helminth control programmes as well as immunology studies in children in Africa are largely school based so as to take advantage of existing infrastructure serving an accessible population. These children tend to be aged 6 years and above which means non-enrolled children below the age of six were being excluded from such programmes. To date no studies have detailed the implementation or epidemiological, pathological, immunological consequences of praziquantel treatment of children aged 5 years and below. The investigation assessed the knowledge of the area inhabitants on schistosomiasis and further assessed the efficacy, safety, and effect of praziquantel treatment in the community.

Sampling

To aid our sampling, class registers were obtained from the school teachers and names extracted for recruiting. Every child in the school register was eligible to participate if willing. The students were assigned study identities that remained the same up to the end of the study. The method of obtaining stool and urine sample was clearly demonstrated to the participants, with children under six years and below getting help from the senior students as well as monitoring by their class teachers. The participants were each given urine and stool specimen bottles labelled with their respective number in the study. Stool and urine specimens were collected from each participant on 3 consecutive days and assayed for S. haematobium, S. mansoni and geo-helminths using standard procedures as detailed below. In case of infants, sample bottles were given to the guardians on three consecutive days to collect urine and stool samples from the infants; at least 2 samples were acceptable for schistosomiasis diagnosis. All samples when collected were brought back to the collection points the next day for processing before distributing more containers for the next samples.

Intensities of S. haematobium infection were calculated from at least 2 urine samples for a maximum of 3, collected over three consecutive days, and those of S. mansoni calculated from mean intensities of at least four Kato-Katz slides for a maximum of 6, two from each of the 2-3 stool samples collected over consecutive days. The participantswere diagnosed as schistosomiasis positive if a single egg of urinary schistosomiasis was observed under the microscope.

Treatment intervention

Children infected with any of the schistosome species were treated with praziquantel at40 mg/kg body weight. Bread and orange juice (500 ml/child or participant) were given as supplementary food following swallowing of the tablets in order to reduce the nauseating effect of praziquantel. Children were also taught about malaria, soil transmitted helminthiasis and schistosomiasis risks. The participants were asked to continuously seek prompt malaria treatment based on recognition of signs and symptoms of malaria that include fever, headache, nausea, general malaise and joint pains. Teachers were asked to continue school health education on schistosomiasis, soil transmitted helminths and malaria; and to encourage children to seek medical care promptly when they felt signs and symptom of malaria irrespective of the presence of the research team. As is standard in all such study designs, after collection of the required samples, all participants were offered treatment with the recommended dose of praziquantel at 40 mg/kg of body weight. No participant presented with malaria during the examinations while it was expected that as an infection that can present in an acute form most of the participants may have been accessing treatment from the local health centres as prescribed by the Ministry of Health in Zimbabwe.

Parasitological techniques

Urine and faecal samples were collected between 1000 hr and 1400 hr in separate wide mouth plastic specimen bottles correspondingly labelled with the laboratory identification numbers assigned to each individual. The samples were processed within two hours of collection. Diagnosis of intestinal helminths (S. mansoni, hookworms, T. trichiura and A. lumbricoides) was based on the detection of worm eggs in faeces, respectively, using the Kato Katz (Katz et al., 1972) method and Formol-ether faecal concentration (FEC) (Cheesbrough, 1998) method for stool. Infection from S. haematobium was diagnosed using the urine filtration technique as described by Mott et al., (1982) as well as the haematuria check using the urinalysis dip-stick method. Urine that is stained red with blood is easy to assess by sight. Normally coloured urine must be assessed using more sophisticated techniques - and the dipstick technique is used. The dipstick technique indicates whether microscopic traces of blood that are invisible to the naked eye arepresent in a urine sample. In terms of sensitivity, the dipstick technique is comparable to that of the urine filtration kit.

Urine filtration assays

The urine specimen was collected between 1000 hours and 1400 hours of the same day for the three consecutive days. It has been found that urinary egg excretion follows a daily rhythm with the peak at noon. The participants brought in labelled urine specimens. The urine sample was mixed and 10 ml of the sample was extracted and forced through a Nytrel filter membrane (pore size 12-20 µm). Schistosome eggs size approximately 150 by 60 µm, are unable to pass through and they are trapped within. The membrane was loosened from its holder and placed on a slide then smeared with 10 % Lugol's iodine solution. The filter membrane was examined under a microscope using the 10X objective. Egg counts were expressed as eggs /10 ml urine (ep10ml).

Feacal Kato-Katz assays

A small amount of faecal matter (40 mg) was taken from the specimen bottle and squeezed past the screen/sieve using an orange stick to let off a smooth faecal material at the back side and debris remained on the inside. The smooth material was taken through to fill a template hole avoiding air bubbles to a slide that had the specimen number on it. The template was carefully lifted leaving the cylindrical drop on the slide. Cellophane material in malachite green which had been soaked overnight was layered on top of the stool sample. Another clean slide was used to sandwich the sample was gently squeezed in a circular motion to give a very thin but smooth circular smear. The slide was placed on the bench with the cellophane upwards to allow for the evaporation of water while the glycerol cleared the faeces. Hookworms were examined within 60 minutes of the slide preparation. S. mansoni was examined later during the course of the surveys. The egg counts were adjusted by multiplying by 24 to give eggs per gram (epg). It is assumed that the standard hole holds 41.7 g of faecal matter. The same procedures were repeated on three consecutive days in order to prevent misdiagnosis due to day-to-day variation of egg excretion. A subject was considered positive for helminth infection if eggs were detected for at leastone helminth in urine or stool. The data collected was analysed for variance using SPSS 8.0 with the 95% confidence level taken at the least level acceptable data.

RESULTS

The Area and population

The rivers in the two communities differed in their temporal distributions - those around the Magaya community are mostly perennial while those around Chitate are seasonal - leading to different schistosome transmission dynamics.

Water contact sites

The main water contact sources were determined from the administered questionnaire and consultation with the local environmental health technician. This revealed contribution of water contact sources as the reason for differences in the level of infection Murewa in the two communities. In the high infection area (Magaya) there are perennial riversproviding habitats for the vectors all year round while the streams in the low infection area (Chitate) are mostly seasonal.

Awareness of schistosomiasis and malaria infection

The aims and procedures of the project were fully explained to participants and their parents/guardians at the beginning of the study and written consent was obtained from the participants and/or parents/guardians before samples were obtained. A questionnaire to obtain the knowledge about the parasite infections was successfully administered to guardians (parents/guardians) accompanying children aged from 6 months to 5 years, bringing a total of 137 children under 5 years old to participate in the study. Analyses indicated that 84% (115) of the guardians were more informed about malaria and childhood infections (children had received vaccinations for BCG, mumps, measles, rubella and diphtheria). About 16% (22) guardians did not know what bilharzia was and whether or not one could catch bilharzia after praziquantel treatment; but 32% (44) knew most of malaria symptoms and that they could contract malaria even after treatment. Fe2wer parents knew how bilharzia was contracted (26%) compared to more than 65% (=5.574, df=1, p=0.018) who knew how malaria was contracted as shown in Figure 2.

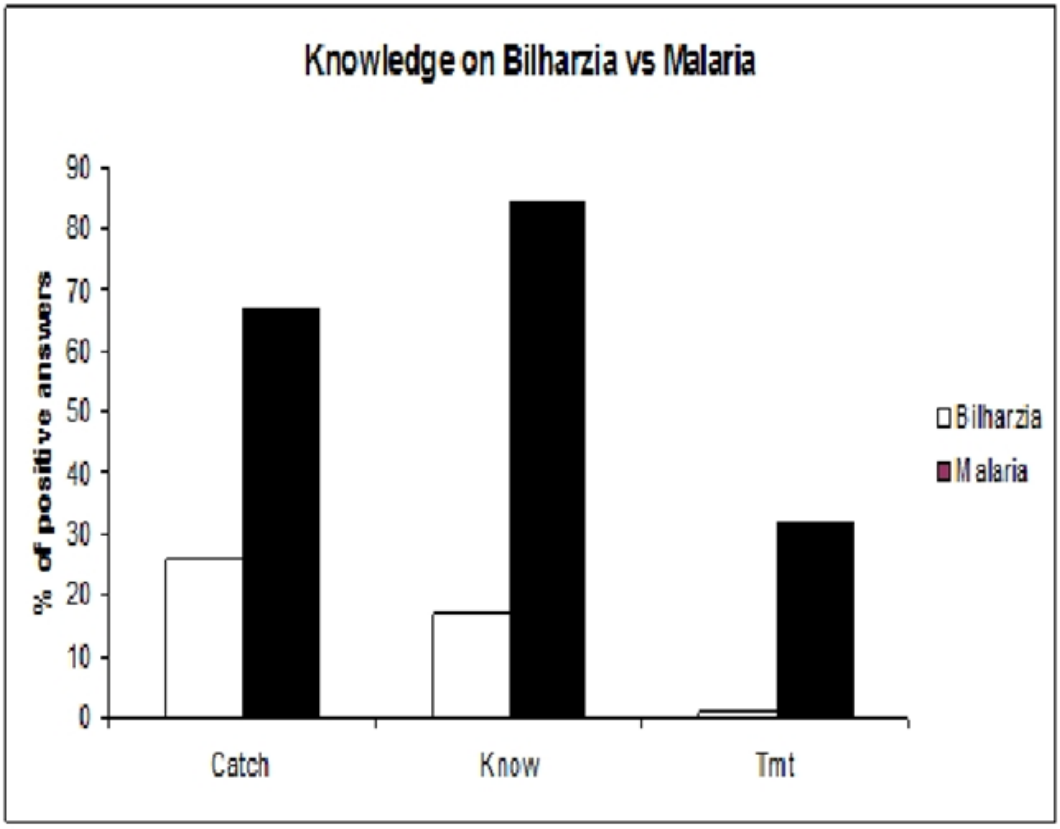

Figure 1: Knowledge of bilharzia and malaria infection and treatment among the guardians of the under 5 years old children. Catch: % know how disease is contracted: know: % know what it is: tmt: % have been treated before. The questionnaire also indicated that all parents responded that they took their children to the local clinic for medical attention when unwell as opposed to self-treating at home with herbal or other medicine, traditional healer or other sources. All parents also indicated that they sought medical attention for themselves at the local clinic. In order to ascertain the source of knowledge, we asked the parents where they had learnt about bilharzia and the majority had learnt about it in school and other community basedactivities proved an important source of information as shown in the pie chart in Figure 2.

The parents were also asked if their children had suffered from a list of symptoms including those related to schistosomiasis and a few parents indicated that their children were passing blood with urine as shown in Figure 3. The poor levels of education in the rural set ups have also been found to be a contribution to the lack of effective malaria eradication (Mengistu et al., 2009; Acka et al., 2012).

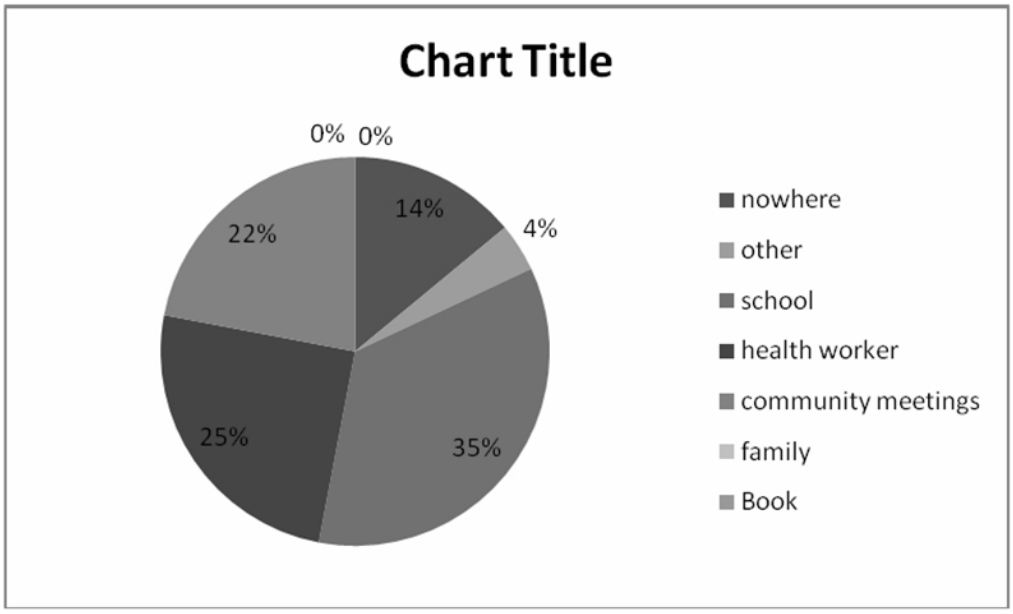

Figure 2: Sources of information about schistosomiasis

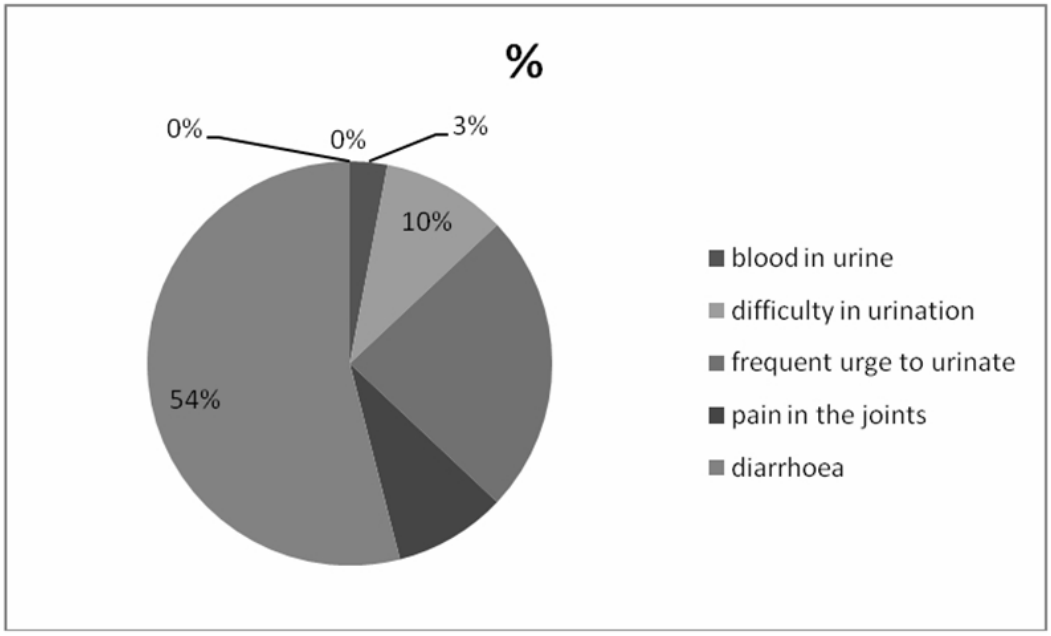

Figure 3: Distribution of the symptoms normally felt by the children

Parasitology and treatment

After the parasitology examination of the whole population in the 2 areas, it was established that the study locations differed in intensity and prevalence of schistosome infection. Schistosome infection

levels were significantly higher in Magaya (prevalence = 69%, 95% CI 63% - 75%) than in Chitate (prevalence = 14%, 95% CI 11% - 18%) (□2 = 187, df=1, p<0.001) with mean infection intensity of 58 eggs/10ml urine (Standard error of the mean, SEM = 8.02) and 15 eggs/10ml urine (SEM = 4.17) respectively (F1,613 =138.2, p < 0.001). According to the WHO's classification of severity of infection, Magaya has high infection (prevalence greater that 50%) and Chitate has moderate infection (50%> prevalence>10%) (WHO, 2002). Infection levels followed the typical age-infection pattern originally described for schistosome infections in 1934 (Fisher, 1934) in which infection rises with age to peak in childhood/early adulthood before declining as shown in Figure 5. There were no stools positive for S. mansoni or other soil transmitted helminths by microscopy for the children aged 5 years and below.

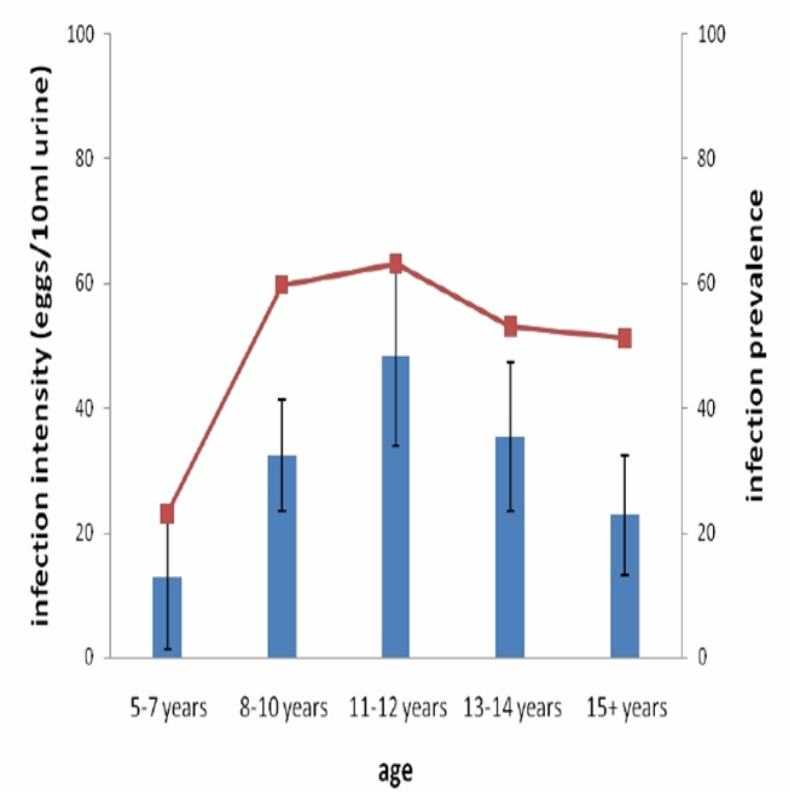

Figure 4: *S. haematobium* infection intensity and prevalence of the whole population examined from the study.

School-aged children displayed the highest burden. This could be due to the long-term cumulative effect of schistosome infection and to the slow development of immunity only evidenced after many years of exposure when puberty occurs (Capron, 1992). Later in life as they turn to puberty and young adults 15-25 years, protective immunity mounted by IgE antibodies progressively take

over, resulting in the partial elimination of the resident worm burden and installation of a more steady state of resistance to re-infections (Hagan et al., 1991).

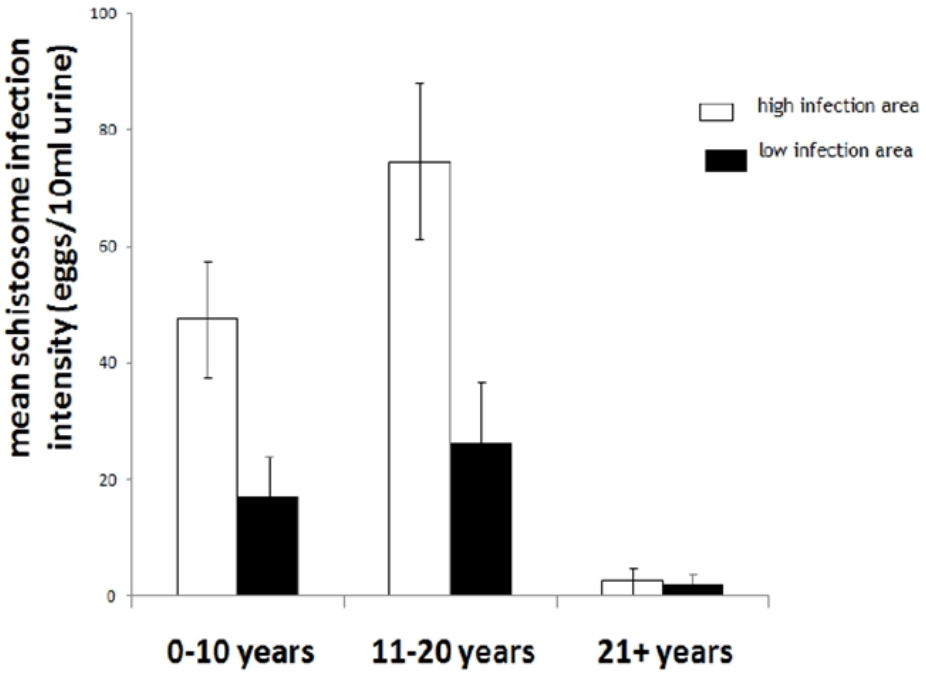

Figure 5: S. haematobium infection intensity in the whole population according to age groups. The data includes the adults from the same area. Sample sizes were Chitate = 681 of which 115 were aged 5 years and below. Magaya n= 482, of which 25 were aged 5 years.

Infection epidemiology

Schistosoma haematobium infection prevalence in the study population was 56% with a mean infection intensity of 34 eggs/10 ml of urine with a standard error (SE) of the mean of 5.5 eggs/ 10 ml urine (range 0-676 eggs/10 ml urine). Although these infection levels are moderate relative to reports from other areas in Zimbabwe and Africa (Dunne et al., 1992), the World Health Organisation denotes this prevalence level as high and infection intensity also as high as defined by having more than 10% of the population with more than 50 eggs/10 ml of urine since 45 of the 227 participants had more than 50 eggs per 10 ml urine (WHO, 2002). Infection rose to peak in childhood (11-12 years) followed by a sharp decline in infection intensity while prevalence fell more gradually as shown in Figure 6. Infection levels in this population peaked at lower levels and in older children compared to high infection areas in Zimbabwe (Dunne et al., 1992). In our study area, that is Chitate and Magaya, there were no other helminths that were detected by microscopy. There was no malaria infection as observed using positive thick smears and confirmed by the rapid diagnostic test kit. However, there is massive coverage on malaria through public media in Zimbabwe and on posters at health centres and schools. Participating children were all treated with

praziquantel tablets at the dose of 40 mg/kg body weight. For infants the tablets were crushed to form a powder, which was administered by the parents/guardians. Bread and orange juice were given and taken just before and after taking the praziquantel tablets. All parents/guardians reported back 24 hours later with the children for the 24 hour check-up on side effects developing from praziquantel administration in children 5 years and below.

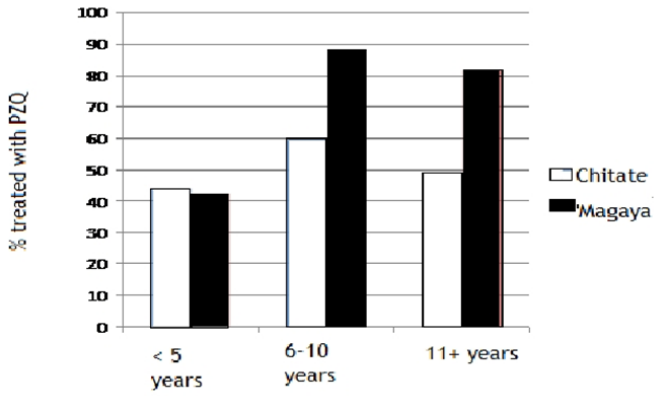

Figure 8: Treatment coverage per age in the study villages

Schistosome-related morbidity before and after praziquantel treatment

Haematuria was measured in the children before treatment and at 6 weeks after treatment using urinary dipsticks (Néphur®, Boerhinger, Mannheim, Germany). Very few childrenshowed intense haematuria, while some of the most intensely infected children especially in the high infection area, Magaya, showed some haematuria. No haematuria was observed in the treated children 6 weeks post-treatment, including the 3% whose parents reported macrohaematuria in the questionnaire.

DISCUSSION

The study area presented with a typical Zimbabwean rural set up where the locals trying to get rid of poverty by utilising available resources like open water bodies, in the process are exposed to infectious agents. With Murewa being a place which receives considerable amount of rainfall, there are some perennial and annual rivers that flow. The hyper- activity of market gardening which is practices, coupled with poor sanitation and hygiene and low levels of health education on schistosomiasis has led into slow progress in elimination of the disease (Zhakary, 1997; Ogbimoko et al., 2010). The WHA recently came out with a resolution to eliminate schistosomiasis (WHO, 2012) but with the current practices and attitudes that were observed in Murewa, and also in Cote d'Ivoire (Acka, 2010) it will prove to be difficult to talk about elimination as yet in sub-Saharan

Africa. The methods that have been heralded as some of the most effective towards schistosomiasis control include vigorous health education, and in this part of the world the aspect is lacking.

We propose that the basic education learning curriculum be included with basic knowledge of the causes, symptoms and cure of most of the neglected tropical diseases. We implore governments and NGOs who are involved inpublic health campaigns to increase awareness on the effects of these diseases that are associated with poverty. The profound effect of de-worming in the school going age group cannot be overstated. Schistosomiasis, caused by a blood fluke, is a debilitating disease affecting school performance and daily activities. Health education on ways to prevent contracting schistosomiasis and facilitating its spread, while seeking treatment when infected would greatly improve health growth in children and school performance. The Zimbabwe government, through the National Institute of Health Research in the early 1990s rolled out a Blair latrine programme where they sponsored villagers to build a Blair latrine. This improved sanitation a bit and could have lead to the containment of the disease, but now with many of such blair latrines having filled up, technologies are required now to assure that the toilet structure that is still usable has its pit revived. With mass treatments and re-treatment after infection having been proved as an effective measure, coupling it with massive health education will bring the much awaited result of eliminating bilharzias or schistosomiasis.

Conclusion and Recommendations

The study gives evidence that the community is poorly educated on bilharzia as compared to knowledge on malaria. The school-going age group is the one that is most affected with bilharzias. Young children from first grade at school are not exempt from infection hence there is also need to be included in the mass treatment schemes. Infection intensity is related to the water contact patterns and the availability of water throughout the year. The study leads to recommendations for health education and support for better sanitation programmes. Effective partnership between stakeholders is essential in the realization of the elimination of schistosomiasis.

Acknowledgements

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SECTION IV:

NATIONAL SECURITY

The impact of the internet on the profitability of retail business models. An empirical analysis of the profitability of e-tailing vis-a-vis traditional retailing

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MBA (Zimbabwe); MBA (Japan).

ABSTRACT

The Internet has revolutionized the retail business, giving rise to Internet-only retailers. This paper argues that despite the cost advantage of online retailers, their profitability is not different from traditional retailers. This study synthesizes ideas from innovation, economics, finance and marketing to evaluate the two retail business models. It investigates retail companies to determine the difference in profitability between Internet-only business models and traditional brick and mortar ones. The theoretical framework is anchored on financial ratios and statistical methods to test the hypothesis. Profitability measures such as GP Margin and NP Margin are used, with samples drawn from Standard & Poor's Compustat database to address the research question. The findings show that there is no (significant) difference between the profitability of both models as measured by accounting ratios. However, the GP margin of e-tailers is statistically much higher than that of traditional retailers.

KEYWORDS:E-tailers; traditional retailers; business models; innovation; GP Margin; NP Margin; Return on Assets; Return on Equity; Return on Invested Capital; profitability.

INTRODUCTION

Retail business models and distribution channels have evolved significantly over the year due to technological advances. In the last decade or so, this change has played out in large part due to the phenomenal evolution of e-commerce (Ow & Wood, 2009).

Business models have a fundamental bearing on firms' ability to generate profits and create a return for investors. Different businesses adopt different models in line with their mission, goals and competitive environment. While Porter(2001:13) scoffs at the term business model, and labels it the '*destructive Internet's lexicon, ...murky at best'*, the term has gained significant traction and use over the years.

Technology irrefutably plays a greater part in defining a firm's business model. Its transformational power is demonstrated by how the Internet has changed the dynamics in the retail industry. Touted as a revolutionary technological innovation, the Internet lowers the cost of doing business and transforms the shopping experience (Hemp, 2006). Interest in the e-tailing business model by investors, entreprenuers, venture capitalists and managers alike has increased over the years (Maubossin & Kawaja, 1999). While a lot of questions have been posed regarding various aspects of e-tailing vis-à-vis the traditional brick-and-mortar retail business model, existing research has not investigated the profitability of the two retailing models to assess the impact of the Internet on retailing. Many authors have asserted that traditional retailers have higher costs compared to their online counterparts (Maubossin & Kawaja, 1999; Latcovich & Smith, 2001), a view which comes from the logic that they employ more people and have higher fixed costs due to their physical assets. While this view is widely held, and is commonsensical, research confirming this view is lacking. This warrants further examination of this view by examining if by virtue of their lower costs, online retailers actually have better profitability compared to traditional brick and mortar ones.This paper examines whether the internet-only retailers are in fact more profitable than traditional retailers. By evaluating the differences between the profitability of the two business models, it becomes possible to see if the internet has in fact had any impact.

The Research Problem

Is the growth in e-tailing a reflection of better returns from that business model compared to the traditional brick and mortar retailing model? Does e-tailing lead to better returns? The research question is: *Is there a difference between the profitability of e-tailers and that of traditional retailers?* To answer it, it is important to investigate how companies using the e-tailing business model have performed compared to the ones that use the traditional model.

OBJECTIVES

The objectives of this research are:

i. To determine the extent to which Internet retailers have performed in terms of profitability after the dot-com bust.
ii. Compare the profitability of Internet retailers with that of traditional retailers to determine which of the two models has better profitability.
iii. Make recommendations on model choice for retailers.

Research scope

The unit of analysis in this paper is the firm. It explores the general trend in the profitability of firms in one industry.

It analyses the financial statements of listed companies from 2002 to 2009. 2002 is a prudent starting point because Internet firms had just started recovering from the dotcom bust. More companies were listed after the year 2000 which makes it possible to make meaningful analyses. Listed companies are an ideal research target as they required publishing their audited financial statements. This provides genuine secondary data.

There is no geographical restriction on companies evaluated, because internet retailers can trade across national borders, and globalization has just made markets more integrated.

Significance of the research

When entrepreneurs invest capital and skills into a venture, the return they seek is as much a function of market forces as it is of their ability to increase the spread between total costs and total revenues. The outcome of this investigation helps in determining whether entrepreneurs in the retail business, whose interest, *ceteris paribus,* is to maximize profits, should pursue a full online business model, retain a traditional model or combine both. The research results also assist academic modeling and theory development.

Operating definitions

De Vaus (2001:24) argues that carrying out research requires developing a nominal definition and operational definition of each concept. The fundamental concepts in this paper are:

i. **E-tailers**: - online retailers using only the Internet as a distribution channel.. Delivery of the purchased product happens subsequent to the online transaction.
ii. **Traditional retailers** – retailers of merchandise who rely on brick and mortar plus other traditional channels like catalogue. Some of them have added websites for online sales, though the latter are not as fundamental to the business model as the physical distribution channels. For this research, the fundamental distiction between e-tailers (i) & (ii) above is the dichotomy that innovation is either sustaining or disruptive(Christensen, 1997),.
iii. **Profitability:**This paper looks at profitability from an accounting perspective. Unlike the economics view, which includes implicit and explicit costs, the accounting perspective views it as as the difference between revenues and explicit costs.

Wang, Chen, & Chang (2004), citing Brown, Gatian and Hicks (1995) state that **return on equity**, **return on investment** and **return on assets** are all closely related and widely used and accepted measures of profitability. These measures are used to answer the research question and their definitions according to the Compustat database from which the data is extracted are as follows:

GP Margin $= \frac{Revenue - Totalcostsofgoodssold}{Revenue} \times 100$

NP Margin $= \frac{Incomebeforeextraordinaryitems}{Revenue} \times 100$

ROA $= \frac{Incomebeforeextraordinaryitems}{TotalAssets} \times 100$

ROE $= \frac{Incomebeforeextraordinaryitems - dividends}{Comonequity} \times 100$

ROIC$= \frac{Incomebeforeextraordinaryitems \times (1 - taxrate)}{Investedcapital} \times 100.$

Hypotheses

H_0 : At a 0.05 level of significance, there is no difference in profitability measures between online retailers and traditional retailers. (H_0: $\mu_1 - \mu_2 = 0$).

H_1: At a 0.05 level of significance, there is a significant difference in the profitability measures of online retailers and traditional retailers. (H_1: $\mu_1 - \mu_2 \neq 0$).

Literature Review

Retailing and the Supply Chain

Retailing is a critical part of the supply chain. Its importance is underscored by the large contribution it makes to the world economy. Yet the industry has certainly evolved and innovated its way over time as businesses compete. Arguably, the Internet has been the most profound innovation in retailing. Some analysts have predicted the beginning of the end of the traditional brick and mortar retailer due to Internet retailing (Schlauch& Laposa, 2001). Yet since the advent of the Internet in 1994, online trade has generated between 2% to 3% of traditional retailers' total turnover (PricewaterhouseCoopers, 2010).

Evolution of the retail industry.

In business, there is a continuous evolution of technologies, driven by a desire to compete and survive. The Darwinism notion of survival of the fittest cannot be separated from the way businesses compete and continuously evolve. Yet, some of the factors that spurred the growth and

evolution of the retail sector were exogenous, for example, it benefitted in part due to innovations in financial sector payment systems – personal cheques and credit cards (Berger, Hancock, & Marquardt, 1996).

From grocery store, warehouses, catalogues to supermarkets

Anderson(2008) comprehensively explores retail industry developments, mostly driven from the USA. From the old grocery store, innovators created catalogue selling, then supermarket. Anderson notes,

> "It took decades for these innovations to emerge and evolve. …Indeed, the true roots of the Long Tail and unlimited shelf space go back to the late nineteenth century and the first giant centralized warehouses… starting in Chicago. …, the era of massive choice and availability arose on towers of wooden pallets built with purchasing afforded by then-new mass production. [pp 41-42].

These retailers led by Richard Sear, founder of Sears, Roebuck & Co. employed volume buying; and utilized railroads, catalogues and the postal system to sell their products.This was followed in 1930 in New York by the advent of the supermarket whose value proposition was offering self-service, abundance, lower prices, one-stop-shopping and choice (Ortega, 1999). The shopping cart was an effective accessory in the evolution of the supermarket. Anderson (2008), citing the Food Marketing Institute, underscores the profound impact of the supermarket as an innovation, by asserting that during the cold war period, around 50000 Soviet Union citizens visited the US 'touring' an American supermarket as part of their visit.

E-commerce and e-tailing

As posited by Anderson (2008), the advent of the Internet in 1994 created the birth of the 'ultimate catalogue'. The advent of the Internet was profound in that it revolutionized the retail sector by opening a new low-cost channel which altered business models completely, creating market niches and opening up unprecedented access to global markets. PricewaterhouseCoopers (2010) notes that,

> "In the West, remote retailing has been developing since the late 1940s. …. The logistics of mail order processing had already been streamlined as new technologies appeared; the principles of catalogue retailing were just transferred to the Internet. [pp11].

Innovation and types of innovation

This retail industry evolution cannot be addressed adequately without discussing innovation. Innovation is a change in the product or service range an organization takes to the market (Johnson, 2001). Johnson's view is certainly inadequate. Levitt (1966) posits that innovation can be viewed from two perspectives: something new that has never been done; or may not be entirely new elsewhere, but new to a specific industry or company. This latter perspective can be stretched to include taking a not so new product to a new market (Foster, 1986). Innovation seems to be distinct from invention, because it happens when an invention has been accepted by society which manifests through high sales and a social and commercial reorganization.

There is an obvious Schumpeterian characteristic to the retail industry innovation, in that it has been destructive, with older concepts being overshadowed by new ones. Yet this is not so in many respects, especially when e-tailing is comparatively evaluated against traditional retailing from a profitability perspective.

Types of innovation

Christensen (1997); and Christensen & Raynor, (2003) argue that a technology is either sustaining or disruptive. The first sort may be incremental, radical or even discontinuous in nature, but "ultimately improves the performance of established products along the dimensions that mainstream customers in major markets have historically valued",(Maubossin & Kawaja, 1999). On the other hand disruptive innovations disrupt and redefine "performance trajectories". They argue thus;

> "Generally, disruptive innovations … consisting of off-the-shelf components put together in a product architecture that was often simpler than prior approaches. They offered less of what customers in established markets wanted… They offered a different package of attributes valued only in emerging markets remote from, and unimportant to, the mainstream." [pp 15].

Christensen also posits the ***value network*** concept, which is the context within which a firm identifies and responds to customers' needs, solves problems, procures inputs, reacts to competitors, and strives for profit. He defines it as,

> "The collection of upstream suppliers, downstream channels to market, and ancillary providers that support a common business model within an industry. When would-be disruptors enter into existing value networks, they must adapt their business models to conform to the value network and therefore fail that disruption because they become co-opted [pp, 296].

Danneels(2004) criticizes Christensen's dichotomy and contends that a disruptive technology is one that alters the competition basis by altering the performance metrics on which firms compete. He further argues that Christensen does not set clear criteria for determining a disruptive technology. Notwithstanding this limitation, Christensen's framework holds tremendous explanatory power for assessing the transformation going on in business. It explains the nature of the "disruptive" change that the Internet has brought upon the retail industry, spawning the question, **is e-tailing, a sustaining or adisruptive technology?** This paper takes the view that the Internet significantly altered the competition metrics in the retail industry, which renders it a disruptive technology.

The **sustaining** versus **disruptive** technology dichotomy in this thesis is underscored by Mauboussin and Kawaja (1999)'s position that traditional retailers have a dilemma on how to deal with this new value network [the Internet].

"This is especially important because most retailers are highly leveraged to changes in incremental revenue. Some view the Internet as a sustaining technology that merely adds another node of distribution to the traditional retail operation. We prefer to view online retail as a disruptive technology.' [pp 3].

This argument forms the basis upon which this paper distinguishes the two business models. Pure online retailers are utilizing disruptive technology whereas brick and mortar retailers have only adopted e-commerce as a sustaining technology to avoid the so-called death from below the 'S-curve'.

Business models

To adequately locate the arguments in existing literature and theory into context, it is necessary to look at what a business model is and how these arguments underpin the research question. Shin & Yongtae(2009)citing the work of Applegate (2001), Timmers (1988), and Weill & Vitale (2001) argue that a number of studies have tried to define the concept of a business model or its major components yet the concept as grounded in its multiple domains remains unclear and poorly defined. They suggest that a business model shows how to make money, making that economic dimension core to any definition of a business model. They further argue that at the core of a business model are business processes. It therefore "seems to refer to a loose conception of how acompany does business and generates revenue," (Porter, 2001). It addresses questions about "what is the underlying economic logic that explains how we can deliver value tocustomers at an appropriate cost?" (Magretta, 2002).

Timmons& Spinelli (2009) suggest that business models drive firms' strategies, and that it comprises the revenue component as well as the cost element, the former being a breakdown of sources of revenue and the latter being a breakdown of how resources are spent, often as represented by the income statement. It is irrefutable that for a business to be competitive, it has to be clear about its business model.

Johnson, Christensen, & Kagermann(2008) suggest that a business model comprises four interlocking elements that create and deliver value, namely key resources, key processes, a customer value proposition and a profit formula. They further argue that business model innovation is critical to an innovation's successful market disruption.

This paper juxtaposes two business models on the basis of Christensen's innovation dichotomy - whether a firm views technology as sustaining or disruptive. Two business models are evaluated, namely e-tailing and traditional retailers. Some traditional retailers sell their merchandise online, but the important thing is that they take a multi-channel approach because they view the Internet as a sustaining technology which simply improves the retailing process.

To emphasize this point, Chen & Liteney (2000) point out that;

> "Unfortunately …there is no generally accepted classification of different types of retailing in the literature. …. Therefore, we suggest a useful way to begin to understand how Internet retailing is different from other forms of retail is to compare Internet retailing with the conventional stores and direct formats". [pp 520]

The long tail

Anderson (2008) propounded the concept of the long tail. It is critical in evaluating the evolution of business models in and outside the retail industry. It puts into perspective the capabilities of the traditional retailing model vis-à-vis the e-tailing one.

The term **long tail** concept derives from the statistical reality that the majority of the population under a normal distribution curve actually lies under the tails rather than under the bell part of the curve. Anderson (2008) posits that there is a rising crop of businesses that make huge profits by selling small volumes of items to a large number of people. Contrary to the Pareto rule, which has been applied in business for many decades; millions of the world's population lie as viable market niches under the tails of the curve; hence the tails are 'long'. According to Anderson;

> "The theory of the long tail can be boiled down to this: our culture and economy are increasingly shifting away from a focus on a relatively small number of hits (mainstream

products and markets) at the head of the demand curve and moving towards a number of niches in the tail. … without the constraints of physical shelf space and bottlenecks of distribution, narrowly targeted goods and services can be as equally attractive as mainstream fare." [pp52].

The advent of the computer in the later part of the 20th century and the development of the Internet and the World Wide Web presented a way to eliminate most of the physical barriers to unlimited selection. Brick and mortar retailers may have economies of scale, but, they have to deal with *'the economics of shelves, walls, locations, working hours and weather'* (Anderson, 2008). The Internet presents a way to surmount these barriers. Anderson posits that the long tail has every product and idea that has never made it into the mainstream of hits.

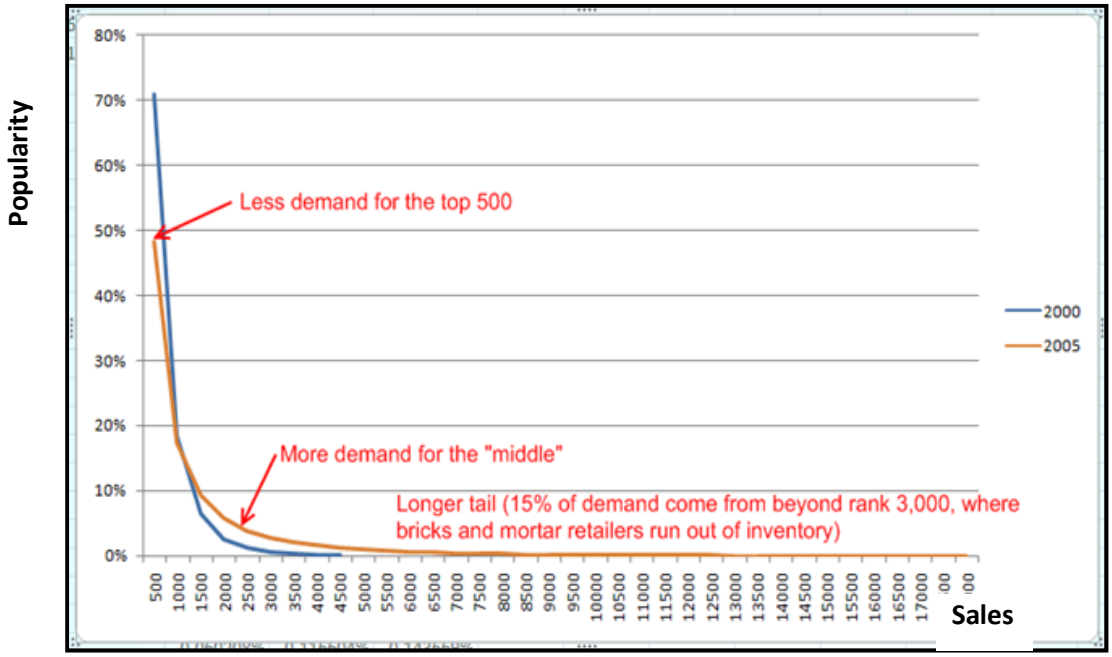

Figure 1: Graphical depiction of the long tail. (Source: www.longtail.com)

The long tail has developed due to innovation and IT advances; due to three forces namely; **democratization of the tools of production**. Personal computers and user-friendly software has enabled everyone to become a low cost producer. As more products are created, this extends the tail further to the right, lowering the cost of the products. The second force is '**democratization of distribution'**. The Internet has enabled everyone to do distribution. Anderson calls this the '*economics of bits versus atoms'*. He argues that;

> "The Internet simply makes it cheaper to reach more people, effectively increasing the liquidity of the market in the tail. That, in turn translates to more consumption, effectively raising the sales line and increasing the sales under the curve". [pp 55]

The third force is an informational role of **'connecting supply and demand'**. Consumers' access to unlimited choice restricted by search costs. Information search costs such as time and money increase costs of purchase. With internet search engines, internet-driven recommendations, blogs and product reviews, consumers now have more product information like performance and price than they had ten years ago.

These forces stretch the tail further out making it *longer*, hence the 'long tail'. This is intensified when some products are converted to electronic formats – the so-called *'from atoms to bits',* which reduces the costs of products such as e-books and e-tickets.

Table 1: Forces & Impact of the Long Tail

Force	**Business**	**Example**
Democratize production	Long tail toolmakers, producers	Digital video cameras, desktop music and video editing software, blogging tools
Democratize distribution	Long tail aggregators	Amazon, eBay, iTunes, Netflix
Connect Supply & Demand	Long tail filters	Google, blogs, recommendations and best seller lists.

Source: Anderson (2008: 57)

Aggregators, in Table 1, arise from the democratisation of distribution. They collect a huge variety of goods and make them available and easy to find in a single place (Anderson, 2008). Anderson suggests that they fall into five categories, namely; physical goods, digital goods, advertising services, information, and comunities/user generated content. They can range from one-man operations to large firms like Google, eBay, Rakuten, Wikipedia and MySpace.

Physical goods and digital goods have varying impacts on the long tail. The former extends the long tail, yet the latter can extend the tail even further down. Anderson calls this digital impact the economic advantage of bits over atoms.

Importance of the Long Tail to Retailing

The democratisation of distribution is about expanding the scope and scale of retailing. Anderson asserts that retail aggregators can be categorised into hybrid retailers and pure digital retailers.The former is a cross between economies of mail order (physical) and Internet (digital) goods. Goods purchased by customers online are delivered through mail or courier. The retailer amasses efficiences by lowering supply chain costs with centralised warehouses and offering unlimited catalogue over the Internet. The only limitation on the long tail is that physical stock has to be warehoused, which comes with inventory risk and shipping costs. However, digital goods are sold without warehousing risks and shipping costs.

Tunesexemplifies the pure digital retailer. Each product is a pure database digital entry sitting on a server somewhere which costs effectivley nothing. The distribution costs are broadband megabytes bought by the customer and incurred when the downloading. Pure downloads have **'near-zero marginal costs of manufacturing and distribution"**.

The difference between traditional retailers and e-tailers

Quite clearly, the distinction between the two retail business models in line with the theory of the long tail is very thin. According to Anderson (2008),

> "…there is no simple divide between traditional retailers and long tail ones. Instead it's a progression from the ecomics of pure atoms, to a hybrid of bits and atoms, to the ideal domain of pure bits. Digitial catalogues of physical goods lower the economics of distribution far enough to get part way down the potential tail. The rest is left to the even more efficient economics of pure digital distribution. Both are long tails, but one is potentially longer than the other." [pp91].

The economics of manufacturing and distribution noted above demonstrate the low cost argument advanced by many scholars as the advantage of e-tailers over traditional retailers.

E-tailers also have an informational advantage as they have more data and insights about their customers than traditional retailers because of their unique ability to capture information about the customer's country, state, precise location, age, and previous purchases among other characteristics. They can also get instantaneous feedback and can make recommendations on what customers looking for a similar product have purchased.

Many scholars are in agreement that e-commerce reduces the cost structure of businesses, due to its wider reach. E-tailers do not suffer from the tyranny of geography, weather or shelves(Anderson,

2008). Vulkan (2003) argues that e-commerce will have major and lasting effects on economic activity, yet the rise and fall in the valuations of the first wave of e-commerce companies show that vague promises of distant profits are insufficient. This suggests that only business models based on sound economic propositions will fulfill those promises.

Disintermediation &Customer satifaction vs shareholder value argument

Chen & Liteney (2000)posit that the traditional retailer is threatened by new intermediaries and disintermediation as shown in the figure below. Yan (2008) did a comparative review of multi-channel traditional retailers and pure play online retailers and concluded that pure play online retailers offer lower prices. An empirical study by Ankaran and Shanker (2004) revealed that multi-channel retailers have the highest prices while e-tailers have the lowest prices (Yan, 2008).

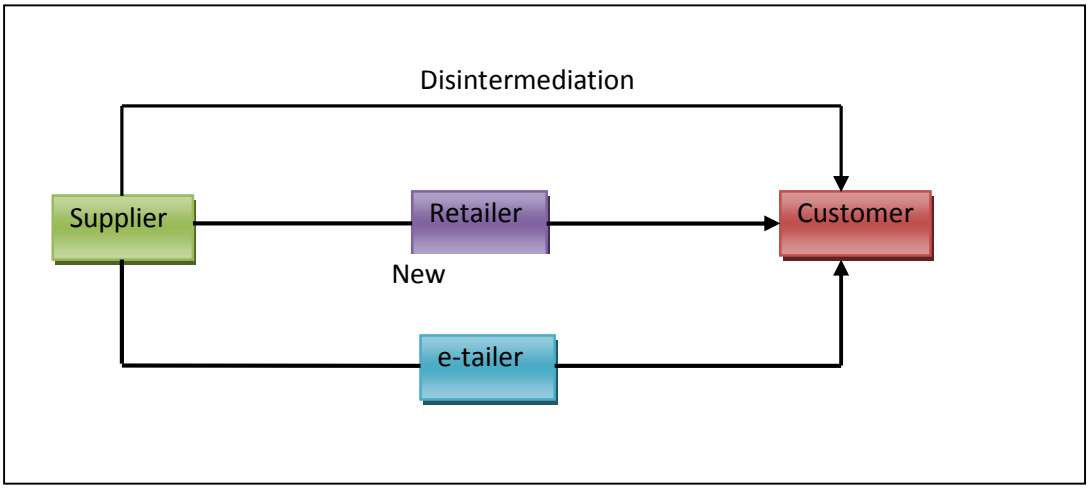

Figure 2: Threats to retailing (Source: Chen & Liteney, 2000)

There is an apparent conflict between the economics of information and the economics of physical goods which accounts for the higher prices offered by traditional retailers (Maubossin & Kawaja, 1999). This conflict is solved in the new value network. Traditional retailers suffer from the conflict between customer satisfaction and shareholder value as customer satisfaction can only be increased up to a certain level after which shareholder value begins to get decimated as the cost of giving more customer satisfaction increase at the expense of shareholder value.

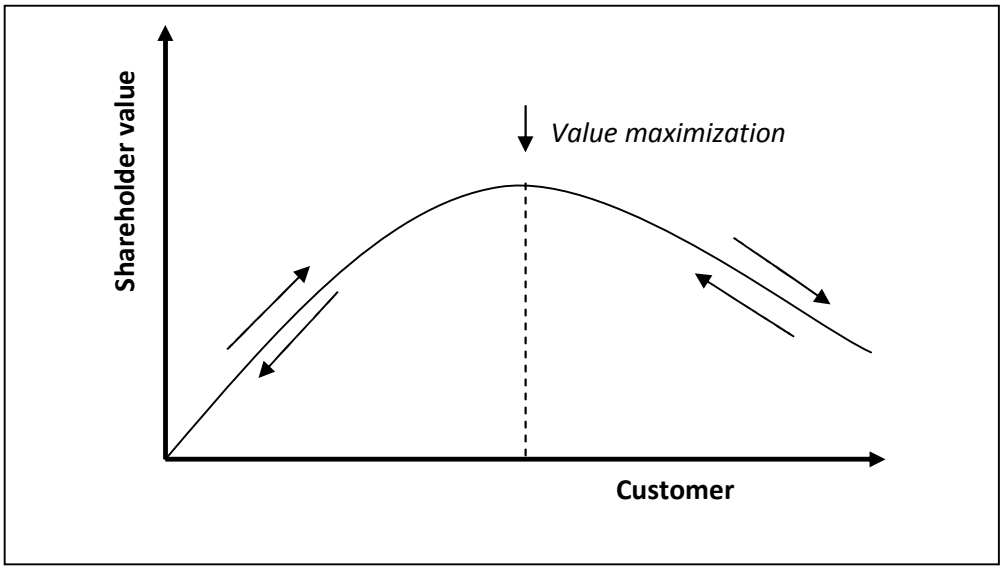

Figure 3: Conflict between shareholder value and customer satisfaction. (Source: Maubossin & Kawaja, 1999)

E-tailers, however, are able to stretch the capability of traditional retailers to offer more customer satisfaction without destroying shareholder value. This similar to Anderson's theory that e-tailing stretches the curve longer down the tail. Competitive advantage can be achieved if the value maximization level is higher for one business model or company than it is for a competing business model or firm and e-tailers seem to have it.

The cost advantage of e-tailers

Anderson (2008)'s 'from atoms to bits' argument lowers e-tailers' maintentance costs more than those of traditional retailers. They save significantly on labour and real estate costs (PricewaterhouseCoopers, 2010). The lower costs culminate in lower prices for consumers. Vulkan (2003) suggests that when e-commerce forces firms to compete on price, this leads to game theory behaviour. He further asserts that:

> "Cost advantage may be the reason for the success of Internet retailers like Amazon , CDNow and Travelocity. But a closer look at the profits of the low cost firm suggests that these profits diminish with the difference between ther own costs and those of their second cheapest competitor." [pp 31]

This view is consistent with Porter (2001)'s criticism that the Internet solely competes on price with the result that it makes industries unattractive as this lowers profits. However, it can be argued that

e-tailers have the capability to engage in dynamic pricing. Technology used by e-tailers can enable them to offer different prices to different markets – price discrimation.

Theoretical Framework

A business' pricing and cost structure impacts on viability, profitability and return to investors. To comparatively evaluate the viability and profitability of business models used by different firms, it is important to look at their respective return on investment. This makes profitability ratios an ideal tool for analysing the profitability of traditional retailers vis-à-vis e-tailers.

The theories and concepts on retail economics, business models, innovation, the long tail and return on investment above help put into perspective work done by other scholars related to this research. Locating this paper in the existing realm of scholarly work done by others helps to shade light on the value it adds.

As noted earlier, this paper aims to test the often held assumptions about e-tailers and retailers, which can be summarised as follows:

- That the Internet retailer has low costs due to less physical infrastructure and low labour costs.
- That due to efficiencies on the cost management side, it should be able to make better margins and hence better profitability.
- That it should generate better revenues because it is able to sell across geographical bounderies because there is no 'tyranny of geography', (Anderson, 2008).

An empirical approach will be taken in answering the research question. Profitability is explored using financial ratios; namely GP margin, NP margin, ROA, ROE and ROIC. These ratios are anchored in accounting theory, which unlike economic theory, looks at profitability differently (Long & Ravenscraft, 1984). The accounting approach is followed because it is widely accepted and practical.Christensen(1997)'s innovation concepts form a strong theoretical underpinning for this paper as it distinguishes the two business models in that e-tailing uses the Internet as a disruptive innovation while the others uses the Internet as a sustaining innovation.

This paper also rests on the Schumpeterian theory of creative destruction. The evolution of retailing points to the reality that business models evolve to replace and cause the death of other models. Evaluating the profitability is key to predicting if e-tailing will eventually eclipse traditional retailing. Figures 5 and 6 below frames the theoretical framework for this paper.

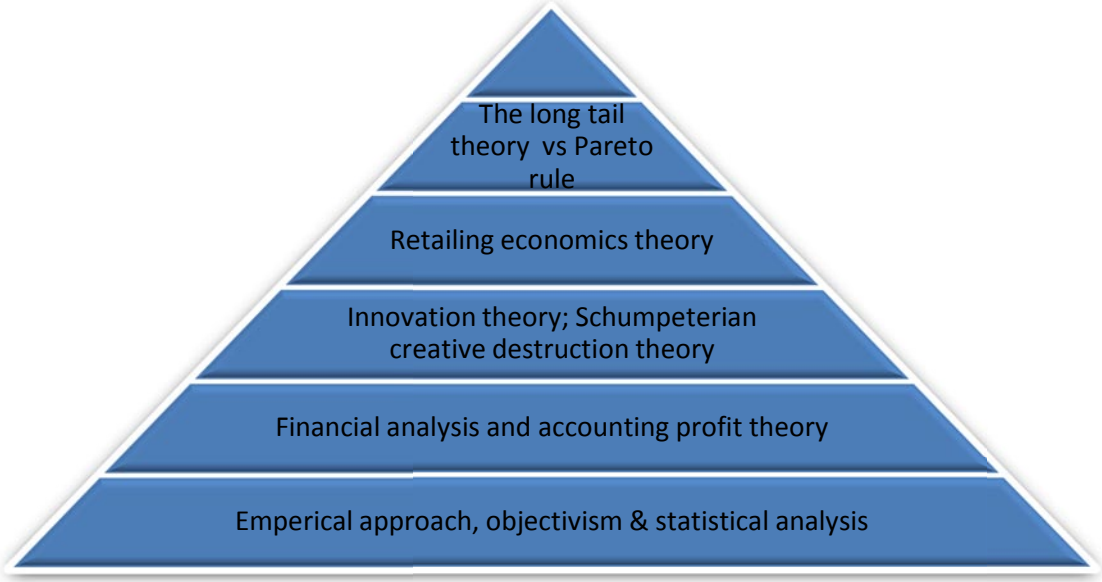

Figure 4: Theoretical basis/framework for the study

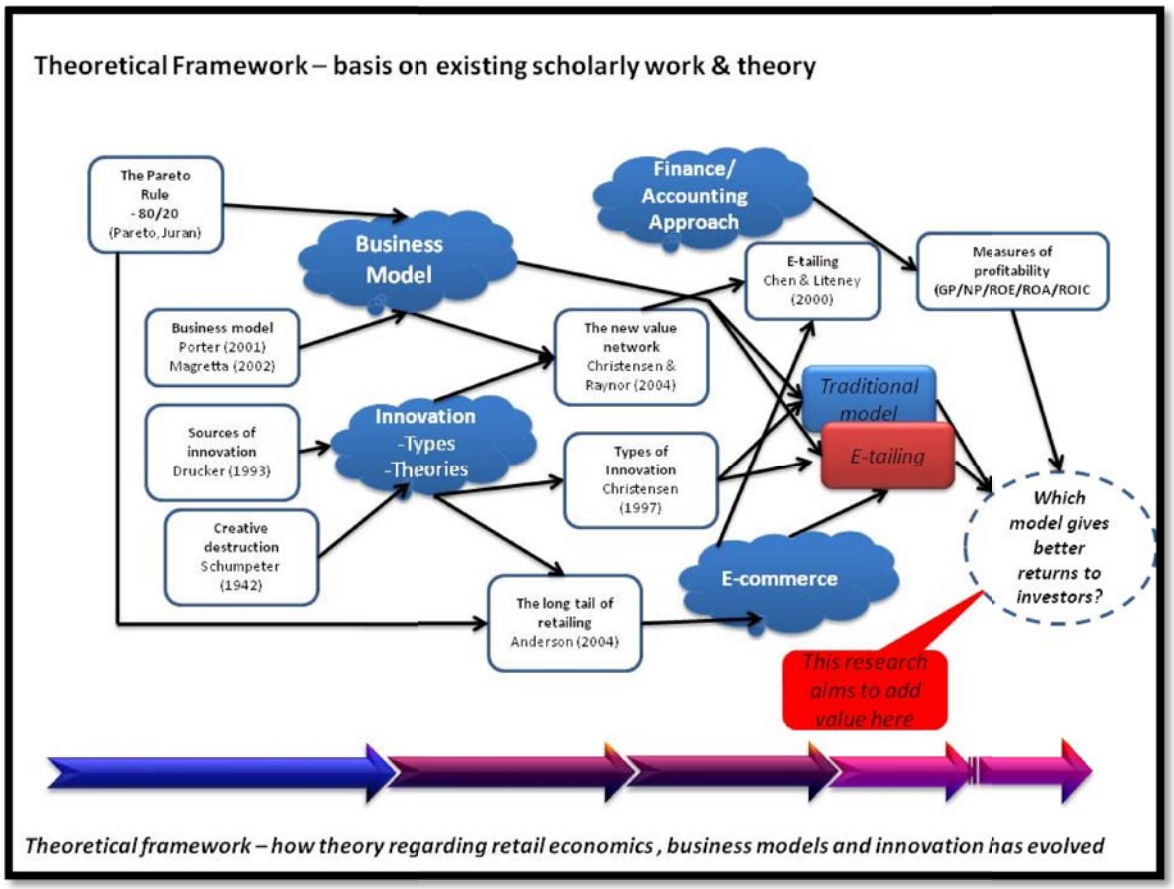

Figure 5: Value added to the existing scholarly work.

METHODOLOGY

Research Approach/Paradigm

Roberts (2010) suggests that there are two broad generic approaches to research methodology, namely the quantitative and qualitative approaches; and that philosophically, quantitative research is "logical positivism" in that the research begins with a clear and specific question and hypothesis, and quantitative data is used to falsify the hypothesis. It also employs concepts like variables, validity and statistical significance (Glatthorn & Joyner, 2005). On the other hand, qualitative research takes a phonomenological dimension in which "reality inheres in the perceptions of individuals to explore meaning and understanding". This study therefore takes a quantitative orientationand positivism is its epistemological foundation. It empirically seeks to answer the research question using stastical testing to falsify or confirm the hypothesis.

This study pursues an inferential approach. As noted by Kothari (2008), the inferential approach creates a database from which inferences and conclusions are drawn about the nature, features and relationships of the population. This invariably entails survey research in which features of a population sample are studied to understand their characteristics and relationships and then inferences are made that the population has the same characteristics.

It is deemed appropriate because the research question is fundamentatlly quantitative. It seeks not just to find the difference in profitability between two business models, but also evaluates their comparative performance in terms of specific profitability measures. Profitability itself is a quantitative dimension measured in numbers. Moreover, it is important to check if the difference in profitability of the two models is statistically significant in order to address the research question and confirm the claim in the hypothesis. It is also necessary to assess the reliability of the computations from a statistical perspective and then come up with conclusions. In addition, there is precedent of the use of this approach in making an analysis of a similar nature by Wang, Chen, & Chang (2004).

The Research method

A research method refers to the technique used to collect the data used to address the research question (Glatthorn & Joyner, 2005). It explains how data is collected to empirically answer the research question and clarifies how the collected data is analysed to test the hypotheses.

Secondary data is used for this paper for a number of reasons. First, collecting primary data would be very difficult because it would be cumbersome, time-consuming and costly. Second, any primary data would be difficult to get as many companies are unwilling to provide profitability and other accounting data beyond what they are required to publish.Third, the necessary data is available in

secondary form and is in an appropriate format from, Compustat – a commercial database. Using secondary data makes it time and cost-effective. In addition, the quality of the data is impeccable because listed firms are independently audited by accounting firms.

However, this has a limitation - that only data for listed companies is used. This point is accentuated by the fact that e-tailers unlisted because the majority of them are start-ups.

e-Tailers and traditional retailers are selected from the database using the GICS for retailing, which a specific industry subgroup for Internet retail. It was accessed using code 25502020 available in May 2011. Other codes are used for traditional retailers, such as code 301010 for food and general retailing.The data collected is from the year 2002 to 2009 – an 8 year periood. Data on GP margin, NP margin, ROA, ROE and ROIC is extracted from the database. For each retailing model, data is extracted separately for each of the ratios.

Samples

After extracting all the data for companies using each of the business models from Compustat, samples are randomly picked for e-tailers and retailers respectively. For each of the five profitability ratios and each retailing model, samples of at least thirty companies are selected using Microsoft Excel. However, for the Internet retailers, some of them are eliminated first as they do not have adequate financial data for the eight-year period. One of the reasons for this is the fact that after the dot-com bust of 2000, many internet firms did not go public, which is why their early 2000 data is unavailable.

Appropriateness of using ratios &Analysis of data

Financial ratios are generally used to analyse financial data.(Wang, Chen, & Chang, 2004) note that financial ratios are appropriate as measures of profitability. Brown, Gatian, & Hicks (1995) assert that financial ratios such as return on assets, return on equity and return on investment are not only closely related, but widely acceptable measures of profitability used both by managers and external analysts.

For each firm selected in the sampling process decribed above, its ratios were extracted from the Compustat database. The extracted data is entered into an Excel spreadsheet. The mean profitability ratios for each firm over the eight-year period are calculated. The mean ratio for each firm in the sample is used in performing the test used to address the hypothesis.

The hypothesis claims that there is no significant difference in each of the profitability ratios between the two retailing business models. Falsifying that hypothesis requires a two sample-test of the hypothesis, which can either be a t-test or a z-test (Lind, Marchal, & Mason, 2002). Given that large independent samples ($n > 30$)are drawn and assume a normal distribution, a z-test of a comparison between 2 independent samples is perfomed to test the hypothesis for each of the ratios. The z-test is carried out using Microsoft Excel as follows:

i. Put sample data for each of the ratios for both business models in Excel.
ii. Calculate the variance for each sample.
iii. Activate the "Data analysis" toolpack as an add in.
iv. Highlight the columns with sample data, and use "data"→"data analysis"→"z-test: two sample means" to compute the statistics at a significance level of 0.05

Research Findings, Analysis and Discussions

Z-Tests and sample sizes

Different samples with varying samples sizes were extracted randomly using Excel for each ratio. Given that$n \geq 30$ was used in each of the cases a Z-test was used to test the hypothesis (Weiers, 2011).The null hypothesis (H_0) states that at a 95% confidence level there is no difference between the mean profitability of the two business models over the period under review profitability ratios.

Gross Profit Margin

For gross profit margin, the Excel computation produced the results shown in Table 2 below.

Table 2: Z-test for mean GP Margin for e-tailers and traditional retailers

Gross Profit Margin		
z-Test: Two Sample for Means $(\mu_1 - \mu_2)$		
	e-Tailers	Retailers
Mean	39.21126	25.5221
Known Variance	436.3963	244.8906
Observations (n)	31	32
Hypothesized Mean Difference	0	
Z	2.936604	
P(Z<=z) one-tail	0.001659	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.003318	
z Critical two-tail	1.959964	
Conclusion	Reject H_0 and accept H_1	

The conclusion was to reject that the hypothesized mean difference between the two samples is zero at the 0.05 level of significance. Two samples were drawn comprising 31 e-tailing companies and 32 traditional retailers. It assumes a normal distribution, because of the large sample size, and the sample standard deviations substitute population standard deviation. In line with the hypothesis, the zero difference implies no difference between the GP margins of the two models. The variance of the samples was calculated at 436.3963 and 244.8306 for e-tailers and traditional retailers respectively, and was used in this test to estimate population variance.

With sample sizes of $n = 31$ and $n > 32$ for e-tailers and traditional retailers respectively, it was a z-test of the means of two independent samples [Lind, Marchal, Mason, 2002]. The hypothesis was a two-tailed test as it equated population mean$\boldsymbol{\mu_1}$to $\boldsymbol{\mu_2}$**.** At the 95% confidence interval, the computed z- value was ± 1.959964 whereas the *p-value,* a probability of finding a test statistic on the extreme when the null hypothesis is true, was 0.003318.

Net Profit Margin

After running a z-test on the NP margin of the two samples, it was concluded that the hypothesis not be rejected, because the hypothesized mean difference of the two independent samples was zero at the 95% confidence interval. Excel computation of the z-test produced the results as shown in

Table 3 below. With a random sample of $n = 31$and $n = 34$, the mean net profit margin was a -1.25376% and 3.295935% for Internet retailers and traditional retailers respectively. The variance was 147.4193 and 55.63398 for the Internet and traditional retailers respectively.

With a hypothesized mean difference of 0, z-value was -1.79958. The test was a 2-tailed (non-directional) with a critical value of ± 1.959964, based on the 95% confidence interval. The conclusion was to accept the null hypothesis.

Table 3: Z-test for mean NP Margin for e-tailers and traditional retailers

Net Profit Margin		
z-Test: Two Sample for Means		
	e-Tailers	Retailers
Mean	-1.25376	3.295935
Known Variance	147.4193	55.63398
Observations	31	34
Hypothesized Mean Difference	0	
Z	-1.79958	
P(Z<=z) one-tail	0.035963	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.071926	
z Critical two-tail	1.959964	
Conclusion	Do not rejectH_0	

Return on Assets (ROA)

The z-test test revealed that the differences in the mean ROA for the two business models were not statistically significant, meaning that the null hypothesis be accepted because the hypothesized mean difference is zero at the 0.05 level of significance. The mean ROA was 0.997% and 2.317% for e-tailers and traditional retailers respectively. With a hypothesized mean difference of zero, the z statistic was 0.51114and the critical value was ± 1.959964.. In carrying out this z-test, sample sizes of $n = 31$ and $n = 35$ were used for e-tailers and traditional retailers respectively. The p-value for the two-tailed test was 0.609254. The z-test output is shown in Table 4 below.

Table 4: Z-test for the mean ROA for e-tailers and traditional retailers

Return on Equity (ROE)

At the 95% confidence interval, it was concluded not to reject the hypothesized mean difference of zero. The ROE shows the level to which shareholders equity has been utilized. Sample sizes of $n = 30$ and $n = 35$ were used for e-tailers and traditional retailers respectively. The mean ROE for the two models was 2.888153% and 2.03559% respectively. The variance of each of the samples was 3967.909 and 1692.199 respectively, implying a standard deviation of 62.9 and 41.1

respectively.

Return on Assets		
z-Test: Two Sample for Means		
	e-Tailers	Retailers
Mean	0.997363	2.317726
Known Variance	135.418	80.65777
Observations	31	35
Hypothesized Mean Difference	0	
Z	-0.51114	
P(Z<=z) one-tail	0.304627	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.609254	
z Critical two-tail	1.959964	
	Do not rejectH_0	

The z-statistic was 0.064201. The critical value determined by the 95% confidence interval was ± 1.959964 whereas the p-value for the test was 0.9. A summary of the test statistics results are shown in Table 5 below.

Table 5: Z-test for the mean ROE for e-tailers & traditional retailers.

Return on Equity		
z-Test: Two Sample for Means		
	e-Tailers	Retailers
Mean	2.888153	2.03559
Known Variance	3967.909	1692.199
Observations	30	35
Hypothesized Mean Difference	0	
Z	0.064201	
P(Z<=z) one-tail	0.474405	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.94881	
z Critical two-tail	1.959964	
Conclusion	Do not rejectH_0	

Return on Invested Capital (ROIC)

Results show that there is no difference in the mean ROIC at the 95% confidence interval. This test was performed with sample sizes of $n = 31$ and $n = 33$ for e-tailers and traditional retailers respectively. The z-statistic was-1.36777, whereas the two-tailed critical value was $\pm$1.959964, determined by the 95% confidence interval. The mean return on invested capital was 1.687148% and 12.20% for e-tailers and retailers respectively. The P-value for the two-tailed test was 0.171384, as shown in Table6 below.

Table 6: Z-test for the mean ROIC for e-tailers and traditional retailers

z-Test: Two Sample for Means		
	e-Tailers	Retailers
Mean	1.687148	12.20625
Known Variance	460.3932	1461.75
Observations	31	33
Hypothesized Mean Difference	0	
Z	-1.36777	
P(Z<=z) one-tail	0.085692	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.171384	
z Critical two-tail	1.959964	
Conclusion	Do not reject H_0	

Tables 7 and 8 below summarize the findings from the statistical test. The last column in Table 7 shows the summary of conclusions based on the 95% confidence level. This column shows that the hypothesized mean difference of zero was contained in the 95% confidence interval for NP Margin, ROA, ROE and ROIC, whereas the GP margin was not contained in the 95% confidence interval.

Table 7: Summary Z-Test statistics of profitability measures

Measure	Model	n. (n>30)	Mean	Standard Deviation	Variance $s^2 = \sigma^2$	P Value
GP Margin	e-Tailers	31	39.21126	20.8901	436.3963	0.003318
	Retailers	32	25.5221	15.64898	244.8907	
NP margin	e-Tailers	31	-1.25376	12.14164	147.4193	0.071926
	B & M	34	3.295935	7.68921	55.6340	
ROA	e-Tailers	31	0.997363	11.6369	135.4180	0.609254
	Retailers	35	2.317726	9.32855	80.6578	
ROE	e-Tailers	31	2.888153	62.9913	3967.9093	0.94881
	Retailers	35	2.03559	41.1363	1692.199	
ROIC	e-Tailers	31	1.687148	21.4568	460.3932	0.171384
	Retailers	33	12.20625	38.8194	1461.7495	

Table 8: Summary Z-Test statistics for e-tailers and retailers

Z-Test statistics	Test statistics			
Measure	Z	Critical Value (2 tailed)	P-value	95% Interval contains 0[1]
Gross Profit margin	2.936604	1.959964	0.003318275	No
Net profit margin	-1.79958	1.959964	0.071926222	Yes
Return on Assets	-0.51114	1.959964	0.609254257	Yes
Return on equity	0.064201	1.959964	0.948809944	Yes
Return on invested capital	-1.36777	1.959964	0.171384327	Yes

DISCUSSION

Distribution channel decisions by any retail business determine its business model because retailers are distributors in the supply chain. Tavlaki & Loukis (2005) suggest that a good business model is a precondition for the success. Porter (2001) argues that despite bringing new ways of doing business, the Internet has led companies to 'make bad decisions' that have eroded industry attractiveness due to competition based on price which undermines their own competitive advantage.

Thepurpose of this paper is to determine the Internet's impact on the profitability of retailing businesses by statistically testing if there are significant differences between the profitability of e-tailers compared to traditional ones.

Gross Profit Margin

Being the excess of revenue over the cost of goods sold, a larger GP margin gives a higher net income assuming expenses are constant. It indicates industry attractiveness (Driffield & Munday, 2000). The z-test warrants a rejection of the null hypothesis and acceptance of the alternative hypothesis. This position was supported by the low p-value of 0.003318. Because the p-value for the z-test for the mean difference of zero was much lower than the level of significance ($p - value < \alpha$), the null hypothesis is unlikely to be true.

[1] *Is the hypothesized difference of zero contained within the 95% confidence interval? If yes, we are 95% confident the population means could be the same.*

We can conclude with 95% confidence that mean gross profit margin between the two models are not the same and the difference in the means is not emanating from sampling error. We can infer that e-tailers have a higher mean GP margin than that of traditional retailers.

Net Profit Margin

Since net profit is the income after covering business expenses, it is logical to argue that it can be enhanced by controlling the business expenses. The computed Z-statistic of -1.79958 fell within this critical value for the two-tailed test. Consequently, there was insufficient statistical evidence to falsify the hypothesis. The p-value of 0.0719, which was larger than the level of significance lends credence and provides additional insight into this conclusion, i.e.,$pvalue > \alpha$.

At the 5% significance level, the data over the eight year period does not provide sufficient evidence to falsify or reject the hypothesis. This means that the difference in the mean NP Margin of - 1.25% for e-tailers and +3.29% for traditional retailers emanated from sampling error. Because the net profit is the residual of gross profit after accounting for expenses, the fact that there was no difference in the net profit margins leads to the inference that the general contention that traditional retailers have more overhead expenses (labour and rentals) cannot be sustained, given the fact that as shown in Table 6 above, the mean GP margin for e-tailers at 39% was higher than that of traditional retailers at 25%. This warrants further research into the expense structure of e-tailers and retailers.

Return on Assets

The calculated z-statistic of -0.511138 for ROA falls within the critical value± 1.95996. At the 5%significance level, the data did not provide sufficient statistical evidence to reject the hypothesis.We are therefore 95% confident that there is no difference between the mean ROA for the two business models. The difference between the two mean ROA of 0.99% for e-tailers and 2.31% for traditional retailers likely arose from sampling error. This conclusion is reinforced by evidence from the p-value of 0.609254, which is much greater than the α of 0.05, suggesting that there is little likelihood that the null hypothesis is false (Lind, Marchal, & Mason, 2002).

Return on Equity

The z-statistic for the mean difference between the return on equity for the two models was 0.0642, which falls between the critical value± 1.95996. There is insufficient evidence to reject the null hypothesis, meaning that at the 5% level of significance, the hypothesized mean difference between

the average ROE for e-tailers and retailers is the same. It follows that the different mean ROEs of 2.888153% and 2.03559% respectively were due to sampling error.

The p-value supports the above conclusion because at 0.94881, it is greater than α= 0.05. There is little likelihood that the null hypothesis is false, implying no difference in the ROE of both business models over the eight year period.

Return on capital invested

The ROIC z-statistic of-1.36777 lies between the critical value of ± 1.95996, meaning that at the 0.05 level of significance, the ROIC data does not provide sufficient evidence to falsify the null hypothesis. Consequently, we are 95% confident that the there is no difference between the ROIC of e-tailers and that of traditional retailers for the period in question. This conclusion was reinforced by the p-value calculation of 0.171384. This p-value was much greater than the significance level of 0.05, meaning that the evidence against the hypothesized mean difference of zero is very weak.Possible underlying causes of the findings

Statistically different GP Margin

As clearly demonstrated above, at the 0.05 level of significance, for the eight year period from 2002 to 2009, the average GP margin for online retailers was statistically different and much higher at 39% than that of traditional retailers at 25%. This means that on average, e-tailers have higher amounts available to contribute to fixed costs and profits.

This finding is profound in that the conventional argument has been that traditional retailers have higher expenses emanating from their physical network and labour costs compared to their counterparts. However, this cannot explain a higher gross profit for e-tailers since GP margin is calculated as gross profit divided by sales multiplied by 100. The gross profit itself is calculated as turnover minus costs of goods sold.

A plausible underlying cause for e-tailers' higher GP margin is either because they get favorable prices from suppliers, which is unlikely, or they have substantial economic advantages from their ability to not hold stock, which has an impact in the calculation of gross profit. Another reason could be that some e-tailers, such as booksellers, do sell some of their stock in digital form (e-books), which substantially lowers the cost of goods sold, unlike their traditional counterparts - the so-called from 'atoms to bits' argument.

Statistically similar NP Margin, ROA ROE & RIOIC

The hypothesis test found that the NP margin was not statistically different for the two business model at the 95% confidence interval. Evidence from the test shows that the margins are not different.

The findings reveal that the mean NP margin for e-tailers is not different from that of traditional retailers yet e-tailers have a higher GP margin. The negative mean net profit margin for e-tailers shown in Table 6 is consistent with the Porter's (2001) questions about the profitability of internet companies. Since the figures of early 2000 , just after the dot.com bust, were incorporated in coming up with the avarage margin calculation, this may have lowered the mean percentage return.

The fact that the ROA, ROE and ROIC are not different at the 5% significant level shows that for the investor, the return was not different whether they invested in an online retailer or a traditional one.

Do these results give new insights? Yes they do. They challenge the commonly held notion that e-tailers have lower costs that should lead to better profit margins and returns. Porter (2001)'s argument, that Internet companies choose to compete on price which results in significantly lower margins making the industry unattractive cannot be sustained by these findings given that e-tailers actually seem to have a higher mean GP margin than their counterparts. Indeed, the argument that e-tailers have to lower prices to counter the advantages that physical stores have can also not be sustained by the their higher GP margin.

Conclusions & Recommendations

Conclusions from the study

This paper reveals the following, contrary to commonly held assumptions:

i. For the eight-year period (2002-2009), for NP Margin, ROA, ROE and ROIC; there is no significant statistical difference in the mean performance of e-tailers and traditional retailers. These ratios measure the so-called bottom-line and reflect how well the business has managed its sales, controlled costs and generated a return for investors. Theoretically, investors and managers would be indifferent to any of the business models on the basis of the NP Margin, ROA, ROE and ROIC. This means that the Internet did not have any impact on these profitability measures in the retailing business.
ii. E-tailers have a higher GP margin, which implies a lower cost of sales.
iii. Even though the GP Margin for e-tailers is significantly higher than that of traditional

retailers, the NP margin is not statistically different. The difference between the gross profit and the net profit are the expenses that are charged to the income statement. Logically, e-tailers likely have more expenses than traditional retailers, though it is not clear which types of expenses contribute towards this situation.

Since there is a difference in the GP Margin for the two models, this ratio is particularly important for management as they can manage the factors that have a bearing on gross profit such as stockholding, returns inwards and outwards and pricing.

Broader Implication of the Findings

The broader implication from the findings from this study on profitability are that given the similarity betweenthe profitability measures of the two business models, model choice on the part of investors, entrepreneurs, retailers and venture capitalist has to be made on the basis of factors other than profitability. The reason is because whichever model they choose, it will produce more or less the same NP Margin, ROE, ROA and ROIC.

RECOMMENDATION

Investors, venture capitalists, managers and entrepreneurs should not use profitability to choose a business model for a retail business, because the bottom-line ratios are not different. Rather, they should consider other factors such as the amount of capital required to finance the venture, among others.

Limitations of the research

A number of limitations with this research need to be noted. These are as follows:

i. The data used to make these evaluations was based on data on listed companies only. Unlisted e-tailers and traditional retailers were not sampled for this analysis, which impacts on the extent of generalization of the findings.
ii. This study used financial ratios to assess the profitability of the two retailing business models. As noted by Wang, Chen, & Chang (2004) there are other quantitative variables that may be used such as market value, stock return and qualitative variables such as leadership, form of ownership, and organisational intellectual capital.
iii. While these findings are of value, they may not have much predictive value, moreso with more and more inovations and evolution in business models, especially in retailing.
iv. The study examined the differences in the means of the proftability ratios over an eight year

period. This tends to mask yearly as well as geographical differences, which limits the aplicability of the conclusions.

Suggestions for future research

The experience from carrying out this study has revealed that there is scope for further research on the following issues:

i. The results reveal that e-tailers have a higher GP margin compared to the traditional retailers, yet both business models yield the same profit margins. If e-tailers have a higher GP margin, yet they eventually end up with the same net profit as the other model, it means that they have a lot of expenses, fixed and variable chewing up much of their gross income from trading. Therefore there is a need to carry out further research on the expense structure of the two business models to see which types of costs contribute to higher total expenses for e-tailers compared with traditional retailers.

ii. There is a need to determine why the GP margin of the two models is different. Such an investigation would invariably have to explore the components of 'costs of goods sold' which is an important part of the gross profit formula. In line with this, there is need to explore the procurement and stockholding practices of each of these business models.

iii. This study has shown that profitability does not account for the growth in e-tailing since there is no difference in most of profitability measures. Therefore there is need to investigate the role other factors such as low capital required to start a business, has played in advancing the growth of online retailers.

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Appendices

Appendix 1：GICS Codes as at June 30 2010

**NB*: This is the relevant portion of the whole set of GICS codes*

GICS (Global Industry Classification Standard)

Effective after close of business (US, EST) Wednesday June 30, 2010

Industry Group		Industry		Sub-Industry
Retailing	255010	Distributors	25501010	**Distributors** Distributors and wholesalers of general merchandise not classified elsewhere. Includes vehicle distributors.
	255020	Internet & Catalog Retail	25502010	**Catalog Retail** Mail order and TV home shopping retailers. Includes companies that provide door-to-door retail.
			25502020	**Internet Retail** Companies providing retail services on the internet, not classified elsewhere.
	255030	Multiline Retail	25503010	**Department Stores** Owners and operators of department stores.
			25503020	**General Merchandise Stores** Owners and operators of stores offering diversified general merchandise. Excludes hypermarkets and large-scale super centers classified in the Hypermarkets & Super Centers Sub-Industry.
	255040	Specialty Retail	25504010	**Apparel Retail** Retailers specialized mainly in apparel and accessories.
			25504020	**Computer & Electronics Retail** Owners and operators of consumer electronics, computers, video and related products retail stores.
			25504030	**Home Improvement Retail** Owners and operators of home and garden improvement retail stores. Includes stores offering building materials and supplies.
			25504040	**Specialty Stores** Owners and operators of specialty retail stores not classified elsewhere. Includes jewelry stores, toy stores, office supply stores, health & vision care stores, and book & entertainment stores.
			25504050	**Automotive Retail** Owners and operators of stores specializing in automotive retail. Includes auto dealers, gas stations, and retailers of auto accessories, motorcycles & parts, automotive glass, and automotive equipment & parts.
			25504060	**Homefurnishing Retail** Owners and operators of furniture and home furnishings retail stores. Includes residential furniture, home furnishings, housewares, and interior design. Excludes home and garden improvement stores, classified in the Home Improvement Retail Sub-Industry.
Food & Staples Retailing	301010	Food & Staples Retailing	30101010	**Drug Retail** Owners and operators of primarily drug retail stores and pharmacies.
			30101020	**Food Distributors** Distributors of food products to other companies and not directly to the consumer.
			30101030	**Food Retail** Owners and operators of primarily food retail stores.
			30101040	**Hypermarkets & Super Centers** Owners and operators of hypermarkets and super centers selling food and a wide-range of consumer staple products. Excludes Food and Drug Retailers classified in the Food Retail and Drug Retail Sub-Industries, respectively.

Appendix 2: Mean data for sample elements for the profitability measures

**NB* This data has been converted as a picture to make it fit on the pages.*

Mean GP margin for the sample elements for the years 2002-2009

Mean Gross Profit Margin	eTailers	Retailers
	24.92513	27.50713
	75.03363	28.04625
	48.26775	35.03138
	22.21875	28.8995
	22.88588	12.29429
	63.14475	25.715
	46.28725	4.797625
	77.21163	30.42288
	30.56775	28.83975
	24.1875	28.997
	23.98429	37.609
	34.67063	13.36938
	16.16213	68.69363
	73.13238	20.12375
	37.6505	27.83888
	41.7205	24.72763
	4.845375	9.7135
	64.22038	4.68575
	28.1215	28.6185
	56.12875	31.00238
	24.90525	17.64963
	41.0625	78.68788
	48.1815	32.10688
	17.475	15.05363
	39.9635	34.34863
	25.09925	24.551
	85.70775	18.70425
	48.63913	23.38813
	6.9235	9.905375
	36.40163	25.82288
	25.8235	10.177
		9.378875
Standard Deviation	20.8901	15.64898
Variance	436.3963	244.8906

Z Test

z-Test: Two Sample for Means

	eTailers	Retailers
Mean	39.2112552	25.5221
Known Variance	436.3963	244.8906
Observations	31	32
Hypothesized Mean Difference	0	
z	2.93660401	
P(Z<=z) one-tail	0.00165914	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.00331828	
z Critical two-tail	1.95996398	
Conclusion	Reject Ho	
Conclusion based on p-value	Reject Ho	
If p-value > LOS, then accept Ho		

Z-test output from Excel

Mean GP Margin for each company in the sample for the 2002-2009

Mean NP margin for the sample elements for the years 2002-2009

Mean Net Profit Margin	eTailers	Retailers
	2.66375	1.441875
	2.947125	0.151875
	0.329125	0.995125
	0.631125	-0.24225
	6.800625	2.100714
	2.575	1.458
	-25.5683	0.101875
	13.52425	3.134125
	-23.0963	3.597
	-7.42463	1.34475
	-1.97871	2.805
	1.34875	1.766875
	-25.7694	5.42425
	7.58825	43.25338
	0.4445	1.179625
	1.99275	1.183625
	0.737625	2.234625
	18.77913	-4.7385
	-0.13975	3.546125
	2.740875	4.101375
	1.686875	8.21625
	2.739875	6.451125
	8.11675	3.573
	-4.049	2.363625
	8.649	1.896375
	-3.47563	-3.67063
	-40.7555	1.948625
	5.988	1.100875
	0.50925	4.017625
	2.823375	1.8682
	-0.2255	4.56675
		0.559875
		2.592375
		1.73825
Standard deviation	12.14164	7.689206
Variance	147.4193	55.63398

z-Test: Two Sample for Means	eTailers	Retailers
Mean	-1.2537609	3.295935
Known Variance	147.4193	55.63398
Observations	31	34
Hypothesized Mean Difference	0	
z	-1.7995848	
P(Z<=z) one-tail	0.03596311	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.07192622	
z Critical two-tail	1.95996398	
Conclusion	Accept Ho	
Conclusion based on p-value	Accept Ho	

Z-test output from Excel.

Mean NP Margin for each company in the sample for the 2002-2009

Mean ROA for the sample elements for the years 2002-2009.

Mean ROA	eTailers	Retailers
	5.90075	2.726875
	1.320625	0.453375
	6.133125	1.438875
	-1.43357	-0.48513
	13.78038	7.094714
	4.865875	4.45525
	-23.2501	0.457375
	9.789875	7.8825
	-13.9261	9.976125
	-14.3191	1.8415
	-7.32714	6.950125
	2.868375	5.84325
	-27.0401	4.454625
	2.577375	10.853
	1.2735	2.592375
	6.600875	3.50775
	3.487625	6.35425
	2.483375	-43.436
	-0.17088	7.875125
	6.984625	3.743875
	5.030714	-7.14575
	5.195	4.816
	24.99363	6.421375
	-12.4284	10.54425
	28.5235	2.92525
	-8.21725	-7.09938
	-4.96338	3.31925
	9.383375	2.179625
	3.943375	6.212375
	2.138375	3.3862
	-3.28	-2.489
		1.9275
		8.558
		2.85775
		0.127125
Standard Deviation	11.63692	8.980967
Variance	135.418	80.65777

z-Test: Two Sample for Means		
	eTailers	Retailers
Mean	0.9973629	2.317726
Known Variance	135.418	80.65777
Observations	31	35
Hypothesized Mean Difference	0	
z	-0.5111382	
P (Z<=z) one-tail	0.30462713	
z Critical one-tail	1.64485363	
P (Z<=z) two-tail	0.60925426	
z Critical two-tail	1.95996398	
Conclusion	Accept Ho	
Conclusion based on p-value	Accept Ho	

Z-test output from Excel

Mean ROA for each company in the sample for the 2002-2009

Mean ROE data for the sample elements for the years 2002-2009

Mean ROE	eTailers	Retailers
	52.1026	8.915625
	247.1794	0.94025
	13.85538	6.54925
	−194.508	−2.90925
	28.83617	23.59243
	6.233625	10.16575
	−53.0521	0.578875
	15.52575	22.87063
	−34.9003	16.6535
	−23.2835	4.315625
	−29.9713	11.66538
	5.672875	12.0315
	−42.8906	8.685125
	1.74925	19.94713
	4.352125	5.82925
	11.897	16.38925
	7.920375	14.08888
	2.44	−216.406
	10.56186	14.415
	15.38725	8.223625
	14.69586	−62.9452
	7.90825	10.57338
	35.14975	11.189
	−58.0803	31.96238
	34.90688	6.56325
	−20.7676	−11.6244
	−25.6693	18.26725
	30.28163	12.51813
	15.43063	16.10438
	2.578	8.4264
	7.990714	−6.47113
		6.524625
		36.87175
		6.55
		0.194
Standard Deviation	62.99134	41.13635
Variance	3967.909	1692.199

z-Test: Two Sample for Means	eTailers	Retailers
Mean	2.88815265	2.03559
Known Variance	3967.909	1692.199
Observations	31	35
Hypothesized Mean Difference	0	
z	0.0642013	
P (Z<=z) one-tail	0.47440497	
z Critical one-tail	1.64485363	
P (Z<=z) two-tail	0.94880994	
z Critical two-tail	1.95996398	
Conclusion	Accept Ho	
Conclusion based on p-value	Accept Ho	

Z-test output from Excel

Mean ROE for each company in the sample for the 2002-2009

Mean ROIC margin for the sample elements for the years 2002-2009

Mean ROIC	e-Tailers	Retailers
	17.41146	5.34775
	62.47341	0.885
	6.994156	2.756
	-49.8339	-1.57863
	18.32592	13.19886
	6.430125	9.63175
	-18.8165	0.6875
	14.01719	16.30663
	-5.54919	15.8115
	-7.86138	3.187625
	-4.67073	9.438375
	6.604	10.07138
	-14.1978	8.33175
	8.781688	16.62975
	3.511813	4.397625
	9.598719	6.093625
	7.962781	14.05113
	-63.7297	215.4549
	8.170277	14.5205
	8.584844	5.419875
	-12.5911	-44.4894
	7.123156	10.26675
	19.43844	9.424875
	-7.00051	27.7445
	18.22972	4.929625
	-11.9272	-11.1646
	-2.26153	8.71525
	13.59069	5.822625
	10.42269	10.23725
	4.132244	4.2286
	-1.06235	-4.57263
		6.488625
		4.531875
Standard deviation	21.45678	38.81937
Variance	460.3932	1461.75

z-Test: Two Sample for Means	eTailers	Retailers
Mean	1.68714765	12.20625
Known Variance	460.3932	1461.75
Observations	31	33
Hypothesized Mean Difference	0	
z	-1.3677692	
P (Z<=z) one-tail	0.08569216	
z Critical one-tail	1.64485363	
P (Z<=z) two-tail	0.17138433	
z Critical two-tail	1.95996398	
Conclusion		Accept Ho
Conclusion based on p-value		Accept Ho

Z-test output from Excel.

Mean ROIC for each company in the sample for the 2002-2009.

Appendix 3: Profitability sample data from Compustat for e-tailers and traditional retailers. ***Gross Profit Margin data from Compustat for e-tailers and traditional retailers (2002-2009)***

Net Profit Margin data from Compustat for e-tailers and traditional retailers (2002-2009)

Retailers									
Firm	2002	2003	2004	2005	2006	2007	2008	2009	Mean
VALOR CO LTD	2.035	1.851	2.191	0.647	1.359	1.301	1.007	1.141	1.441875
CPS CORP	0.639	0.554	0.442	0.703	-2.217	0.292	0.351	0.441	0.151875
COSTCO WHOLESALE CORP	1.806	1.695	1.834	2.008	1.834	1.668	1.77	1.52	1.766875
MARUETSU INC	0.324	0.288	-5.992	-2.92	1.079	1.404	1.812	2.067	-0.24225
MAXVALU NISHINIHON CO LTD	1.268	0.707	1.09	1.075	1.675	1.973	1.981	1.895	1.458
CHUO GYORUI CO LTD	-0.102	0.16	0.331	0.319	0.663	-0.047	-0.798	0.289	0.101875
PRESIDENT CHAIN STORE CORP	3.239	4.218	3.312	3.218	3.046	2.702	2.494	2.844	3.134125
WALGREEN CO	3.554	3.617	3.599	3.695	3.693	3.797	3.654	3.167	3.597
WALMART CHILE SA	2.268	1.79	0.369	2.376	2.337	2.764	0.982	-2.128	1.34475
WHOLE FOODS MARKET INC	3.14	3.293	3.432	2.9	3.635	2.772	1.44	1.828	2.805
SIAM MAKRO PCL	2.528	2.342	2.409	2.189	2.146	2.031	2.274	1.958	2.234625
FAMILY MART CO LTD	5.922	6.021	4.991	5.135	5.025	5.146	5.725	5.429	5.42425
FOODCO HOLDING PJSC	5.359	8.604	84.722	130.952	51.796	22.922	17.445	24.227	43.25338
HARASHIN NARUS HLDGS CO LTD	1.257	0.879	1.222	1.412	1.168	1.376	0.916	1.207	1.179625
KROGER CO	2.382	0.58	-0.177	1.582	1.687	1.681	1.643	0.091	1.183625
LAWSON INC	3.54	7.561	8.033	8.217	7.413	7.344	6.812	2.689	6.451125
BOOKER GROUP PLC	-17.078	-11.928	-8.877	-3.993	0.362	0.968	1.233	1.405	-4.7385
CONVENIENCE RETAIL ASIA LTD	5.175	3.978	3.81	3.688	3.364	2.978	2.675	2.701	3.546125
CENCOSUD SA	6.232	4.794	3.64	4.047	4.118	5.559	2.612	1.809	4.101375
CP LOTUS CORP	113.17	18.777	-13.299	-26.484	-16.026	-7	-0.724	-2.681	8.21625
METRO AG	0.86	0.925	1.466	0.897	1.525	1.326	1.224	0.581	1.100875
SAN-A CO LTD	3.362	3.381	3.41	3.443	3.661	3.945	3.737	3.645	3.573
AXFOOD AB	1.887	2.085	1.963	2.613	2.958	2.676	2.328	2.449	2.363625
JOHN LEWIS PARTNERSHIP PLC	0.97	1.371	1.478	1.841	1.902	2.302	3.726	1.581	1.896375
MARUYA CO LTD	1.395	1.171	0.234	-3.205	-12.035	-8.061	-5.538	-3.326	-3.67063
CARREFOUR SUPERMARCHE SA	2.021	2.298	2.287	2.43	2.384	2.275	1.444	0.45	1.948625
TESCO PLC	3.592	3.57	4.021	4.005	4.395	4.491	3.978	4.089	4.017625
DELHAIZE AMERICA INC	1.673	1.485	1.957	2.062	2.214	@NA	@NA	@NA	1.8682
HIPERMARC SA	-0.256	-3.382	-5.957	-7.372	-6.694	-17.343	65.179	12.309	4.56675
ITOCHU-SHOKUHIN CO LTD	0.729	0.628	0.629	0.425	0.761	0.424	0.307	0.576	0.559875
MASSMART HOLDINGS LTD	1.925	2.108	2.364	2.285	2.759	3.042	3.36	2.896	2.592375
SAINSBURY (J) PLC	2.605	2.31	0.396	0.398	1.895	1.844	1.528	2.93	1.73825
OLYMPIC CORP	1.328	1.252	-0.279	0.255	-2.864	0.074	0.347	0.111	0.02925
AEON CO LTD	1.661	1.56	1.479	0.653	1.195	0.85	-0.053	0.616	0.995125

E-tailers									
Firm	2002	2003	2004	2005	2006	2007	2008	2009	Mean
KOMPLETT ASA	100	100	100	7.553	8.155	6.533	5.377	6.146	41.7205
ARTNET AG	69.17	82.971	81.639	79.336	80.882	81.173	59.888	65.21	75.03363
ASOS PLC	93.056	54.399	51.087	49.075	43.631	33.91	30.411	30.573	48.26775
B2W - COMPANHIA GLOBAL DO	6.306	12.854	13.941	27.764	29.791	29.672	29.371	28.051	22.21875
AMAZON.COM INC	27.331	25.319	24.23	25.347	24.797	24.341	23.902	24.134	24.92513
BUCH.DE INTERNETSTORES AG	100	100	100	100	26.982	25.884	26.027	26.265	63.14475
CENTRO HL DISTRIBUZIONE SPA	100	100	100	20.545	15.313	13.684	10.787	9.969	46.28725
DIGITAL ADVENTURE INC	8.977	33.369	35.52	34.307	25.4	39.175	41.873	25.921	30.56775
DRUGSTORE.COM INC	24.217	23.058	22.525	21.867	21.584	23.289	28.065	28.895	24.1875
EXPANSYS PLC	@NA	26.136	23.462	23.031	24.749	22.789	26.488	21.235	23.98429
GOLF DIGEST ONLINE	27.555	29.402	33.212	34.842	35.636	38.208	37.836	40.674	34.67063
HOLLYWOOD MEDIA CORP	10.179	29.485	28.993	12.145	15.847	11.656	9.304	11.688	16.16213
INTERPARK CORP	12.79	100	100	100	90.51	41.104	100	40.655	73.13238
KENKO.COM INC	47.418	40.929	37.496	35.762	35.689	35.216	33.844	34.85	37.6505
DENA CO LTD	59.482	79.655	81.638	77.757	75.058	82.923	80.238	80.942	77.21163
LDLC.COM	4.902	6.113	3.71	-0.527	-0.044	8.204	8.817	7.588	4.845375
MEDIANTIS AG	100	100	100	49.738	39.755	37.785	39.879	46.606	64.22038
MINERVA HOLDINGS CO LTD	24.58	31.073	26.51	30.045	28.893	28.223	28.246	27.402	28.1213
NETFLIX INC	66.193	64.235	62.812	47.41	52.858	53.44	51.28	50.802	56.12875
NETONNET AB	12.142	15.042	15.365	100	13.156	14.039	15.359	14.139	24.90525
NETPRICE.COM LTD	50.988	39.622	40.116	41.614	41.611	36.58	39.111	38.858	41.0625
NUTRISYSTEM INC	43.088	40.766	43.12	48.505	52.237	53.155	50.758	53.823	48.1815
OVERSTOCK.COM INC	22.026	11.625	14.187	16.94	16.13	20.113	19.844	18.935	17.475
PETMED EXPRESS INC	42.67	40.609	40.291	39.495	39.795	39.405	38.889	38.554	39.9635
RACCOON CO LTD	32.528	29.438	34.002	29.052	22.885	18.686	17.427	16.776	25.09925
RAKUTEN INC	82.08	99.264	90.122	90.005	87.019	81.841	78.307	77.024	85.70775
START TODAY CO LTD	36.538	35.531	37.699	43.89	54.812	59.623	60.574	60.446	48.63913
STREAM CO LTD	6.094	4.774	4.594	6.487	7.429	7.824	8.378	9.808	6.9235
VECTOR INC	34.365	34.625	30.624	30.054	31.648	38.215	39.014	52.668	36.40163
YES24 CO LTD	18.158	24.104	27.046	26.217	27.067	28.263	28.059	27.674	25.8235
BLUE NILE INC	27.607	23.827	23.14	23.065	20.955	20.978	21.029	22.486	22.88588

ROAdata from Compustat for e-tailers and traditional retailers (2002-2009)

Firm	2002	2003	2004	2005	2006	2007	2008	2009	Mean
CARREFOUR SUPERMARCHE SA	3.568	4.147	4.264	3.914	3.907	3.598	2.411	0.745	3.310625
METRO AG	1.933	1.866	2.941	1.738	2.01	2.512	2.16	1.132	2.179625
MAXVALU NISHINIHONCO LTD	3.029	2.193	3.261	3.229	5.316	6.103	6.201	5.32	4.455625
CHUO GYORUI CO. LTD	-0.521	0.813	1.638	1.528	3.101	-0.221	-4.011	1.333	0.457375
PRESIDENT CHAIN STORE CORP	8.853	11.602	8.981	8.135	7.763	6.921	5.523	6.086	7.8875
WALGREEN CO	10.317	10.308	10.117	10.675	10.219	10.569	9.625	7.979	9.976125
AEON CO LTD	2.546	2.12	2.255	0.988	1.651	1.223	-0.074	0.822	1.438875
MARUETSU INC	0.75	0.644	-14.996	-7.389	2.891	5.788	4.932	5.519	-0.485125
COSTCO WHOLESALE CORP	6.024	5.496	5.847	6.436	6.306	5.522	6.202	4.941	5.84325
FAMILY MART CO LTD	5.139	4.457	4.402	4.519	4.748	4.68	4.152	3.56	4.454625
FOODOO HOLDING PLC	2.969	3.711	23.036	28.707	12.916	4.559	5.973	4.853	10.85375
MARASHINARUS HLDGS CO LTD	2.501	1.783	2.658	3.255	2.557	3.154	2.044	2.787	2.592375
KROGER CO	6.134	1.503	0.488	-4.677	5.256	5.296	5.381	0.303	3.50775
SIAM MAKRO PCL	5.713	5.838	5.971	5.992	6.343	6.222	8.093	6.662	6.35425
DOOKER GROUP PLC	-162.69	-150.151	-33.753	-17.562	1.453	3.823	5.057	5.721	-43.4375
CONVENIENCE RETAIL ASIA LTD	11.022	8.82	8.595	8.366	7.672	5.84	5.853	5.933	7.875125
CENCOSUD SA	3.055	3.086	3.219	4.077	4.453	5.416	2.901	1.044	3.743875
CP LOTUS CORP	11.656	4.056	8.984	25.738	22.607	12.465	0.538	3.361	7.14575
LAWSON INC	2.586	5.234	5.735	5.872	5.269	5.57	5.459	2.803	4.816
SAN A CO LTD	6.533	6.107	6.791	6.376	6.681	7.122	6.088	5.673	6.421375
AXFOOD AB	9.492	9.804	9.429	9.697	11.025	11.919	10.027	11.055	10.54125
JOHN LEWIS PARTNERSHIP PLC	1.515	2.206	2.331	2.719	2.937	3.654	5.779	2.262	2.92525
MARUYA CO LTD	2.161	2.192	0.127	-5.267	-23.552	-16.914	-10.329	-5.813	-7.08938
WALMART CHILE SA	3.148	2.165	0.51	3.11	3.29	3.68	1.241	-3.012	1.8415
WHOLE FOODS MARKET INC	8.958	8.664	8.571	7.217	9.977	5.687	3.388	3.139	6.950125
TESCO PLC	5.739	5.926	6.693	7.003	7.551	7.012	4.692	5.056	6.212375
DELHAIZE AMERICA INC	2.915	2.571	3.472	3.701	4.266	@NA	@NA	@NA	3.38667
HIPERMARCSA	-0.157	-2.356	-4.074	-5.262	-5.267	-19.338	14.863	1.679	-2.489
ITO CHU SHOKUHIN CO LTD	2.609	2.735	2.788	1.517	2.328	1.397	1.073	2.053	1.9375
MASSMART HOLDINGS LTD	6.506	7.309	7.987	7.501	8.591	9.759	11.012	9.666	8.558
SAINSBURY (J) PLC	3.774	3.145	0.525	0.502	3.394	3.253	2.88	5.389	2.85775
OLYMPIC CORP	2.212	2.015	-0.412	0.365	-1.111	0.122	0.586	0.18	0.377125
UNIQLO LTD	3.853	3.568	3.263	1.285	2.508	2.513	1.989	2.336	2.726875

Firm	2002	2003	2004	2005	2006	2007	2008	2009	Mean
RAKUTEN INC	9.62	27.099	4.64	1.173	0.208	3.184	5.058	3.045	4.06388
BLUE NILE INC	5.263	13.313	7.779	9.531	10.699	10.972	12.971	9.215	13.78038
ASOS PLC	-53.693	13.542	13.636	13	14.79	13.891	16.291	17.615	6.133125
B2W - COMPANHIA GLOBAL DO	-26.981	-1.807	1.124	5.685	@NA	3.136	3.155	2.018	-1.43857
NETPRICE COM LTD	23.385	18.216	12.877	3.115	-5.17	-12.581	0.177	1.294	5.195
BUCH.DE INTERNETSTORES AG	-10.162	35.86	0.875	3.809	4.706	-1.691	2.883	2.647	4.865875
CENTRO HL DISTRIBUZIONE SPA	-51.741	-37.41	-35.812	-10.806	-1.891	-4.416	-44.139	0.213	-25.2501
DENA CO LTD	-30.141	14.785	7.957	11.185	12.022	20.629	21.51	20.572	9.788875
DIGITAL ADVENTURE INC	-27.018	5.766	-4.257	-22.676	-58.676	8.551	1.411	-12.51	-15.9281
DRUGSTORE.COM INC	-52.305	-10.115	-30.115	-12.255	-7.759	-6.562	-10.729	-4.739	-14.5191
EXPANSYS PLC	@NA	18.921	2.34	-5.686	-3.431	-9.916	-30.951	-22.567	-7.32714
GOLF DIGEST ONLINE	-8.496	5.865	7.578	3.152	-0.556	3.522	5.373	7.569	2.868375
HOLLYWOOD MEDIA CORP	131.386	13.083	16.613	10.699	7.435	10.408	15.783	10.824	27.0401
INTERPARK CORP	21.17	16.467	8.742	1.97	13.775	2.738	0.968	53.023	2.577875
IRENIO.COM INC	0.272	15.31	-3.054	1.82	0.357	-3.004	-2.438	1.525	1.2725
NOMPLETT ASA	13.389	12.368	5.629	0.54	10.697	3.247	4.854	2.791	6.600875
LDLC.COM	13.128	15.22	6.636	8.056	5.984	2.69	3.384	0.883	3.487625
MEDIANTIS AG	6.292	7.841	7.701	5.788	1.814	1.728	0.756	1.541	2.483875
MINERVA HOLDINGS CO LTD	27.17	7.807	22.363	8.148	16.475	8.930	6.61	0.187	0.17088
NETFLIX INC	16.814	3.7	8.576	11.524	8.062	10.348	13.436	17.045	6.984625
NETONNET AB	8.094	3.691	4.211	@NC	2.41	6.22	7.614	2.395	5.030714
NUTRISYSTEM INC	26.713	5.932	5.717	19.595	13.021	52.851	29.113	17.001	24.90363
OVERSTOCK.COM INC	-18.095	-17.131	-1.752	-7.702	-37.079	-19.081	-7.31	3.556	-12.4281
PETMED EXPRESS INC	36.096	31.459	28.186	28.303	23.591	27.357	28.032	21.961	28.5235
RACCOON CO LTD	-44.369	-21.97	11.509	7.668	-19.255	-9.975	5.251	5.403	-8.21725
VECTOR INC	3.01	3.611	5.067	2.353	-1.188	-1.911	-1.727	8.172	2.138875
START TODAY CO LTD	0	2.899	8.18	4.779	12.406	15.712	15.617	15.119	9.388875
STREAM CO LTD	3.454	2.619	-1.207	5.151	8.384	7.175	4.283	1.688	3.943875
VPS 21 CO LTD	-13.855	-30.982	0.521	3.581	5.139	13.838	8.697	6.766	-3.28
AMAZON.COM INC	-7.533	1.632	12.114	9.01	4.355	7.31	7.758	6.53	5.90075
ARTNET AG	-25.936	-46.86	-39.663	50.839	53.138	32.572	-6.421	-7.104	1.320625

ROEsample data from Compustat for e-tailers and traditional retailers (2002-2009)

E-tailors

Firm	2002	2003	2004	2005	2006	2007	2008	2009	Mean
BUCH.DE INTERNETSTORES AG	-15.912	46.632	1.115	5.302	6.325	-2.433	4.496	4.344	6.233625
EXPANSIS PLC	@NA	74.654	21.556	-86.125	-6.425	-29.064	-96.582	-87.812	-29.9713
B2W - COMPANHIA GLOBAL DO	-1356.33	@NC	106.693	9.941	@NC	19.287	34.686	19.277	-194.308
BLUE NILE INC	@NC	@NC	11.943	16.136	27.618	27.504	60.234	29.582	28.83617
APTINET AG	@NC	@NC	@NC	1.106.73	102.344	51.228	-11.667	-12.739	247.1794
CENTRO HL DISTRIBUZIONE SPA	-131.542	-100.256	-77.314	-16.015	-2.928	-7.146	-89.57	0.354	-53.0521
ASOS PLC	-92.597	20.457	24.308	27.148	28.849	31.692	38.932	32.059	13.85358
DIGITAL ADVENTURE INC	-44.485	5.102	-4.923	-42.787	-187.041	13.029	1.934	-20.081	-34.9003
DENA CO LTD	-39.856	22.456	9.243	13.657	18.799	33.826	33.022	32.859	15.52375
KENKO.COM INC	1.19	44	-5.132	3.15	0.615	-7.045	-5.241	3.28	4.352125
AMAZON.COM INC	@NC	@NC	@NC	135.366	44.084	39.766	24.139	17.158	52.1026
GOLF DIGEST ONLINE	-19.277	14.426	11.327	5.108	-1.098	8.496	11.45	14.951	5.672375
HOLLYWOOD MEDIA CORP	-197.491	-21.706	-24.599	-21.022	-13.35	-17.744	-28.013	-19.2	-42.8906
INTERPARK CORP	-42.717	-37.43	-31.468	15.357	42.442	-6.445	2.167	72.088	1.74925
MEDIANTIS AG	6.848	8.401	8.372	9.529	2.843	2.619	-16.705	-2.387	2.44
NOMPLETT ASA	24.434	22.261	10.653	17.101	19.467	5.353	-8.529	4.436	11.397
LDLC.COM	28.829	46.194	18.566	-31.189	-21.862	9.344	10.786	2.695	7.920375
DRUGSTORE.COM INC	-44.102	-14.545	-54.787	-21.708	-14.055	-12.98	-17.375	-7.498	-23.2335
MINERVA HOLDINGS CO LTD	@NC	59.155	-50.316	14.785	27.713	12.421	9.852	0.323	10.56186
NETFLIX INC	-24.561	5.778	13.818	18.575	11.85	15.543	23.916	58.179	15.38725
NETONNET AB	16.932	8.19	14.12	@NC	8.383	21.365	24.398	9.483	14.69586
NETPRICE.COM LTD	35.185	27.172	16.963	4.813	-7.151	-16.372	0.6	2.056	7.90825
NUTRISYSTEM INC	42.122	8.74	8.37	26.613	58.588	74.166	40.084	22.515	35.14975
OVERSTOCK.COM INC	-29.47	-22.124	-2.784	-27.97	-153.287	-242.214	@NC	71.287	-58.0808
PETMED EXPRESS INC	58.345	41.57	33.088	32.06	26.821	29.872	30.651	26.848	34.90888
RACCOON CO LTD	-95.588	-75.325	26.012	10.049	-32.038	-20.305	10.045	11.009	-20.7576
RAKUTEN INC	-10.84	-199.67	-31.123	25.407	1.433	19.841	-36.665	26.263	-25.6693
START TODAY CO LTD	0	32	67.089	40.741	27.539	24.57	23.769	26.958	30.28153
STREAM CO LTD	30.882	21.429	-5.319	23.214	25.654	14.953	8.338	4.294	15.43063
VECTOR INC	3.528	4.228	6.259	2.852	-1.862	-2.49	-2.243	10.352	2.378
VES24 CO LTD	@NC	-64.588	2.018	19.133	23.669	44.532	18.013	13.158	7.990714

Retailers

Firm	2002	2003	2004	2005	2006	2007	2008	2009	Mean
VALOR CO LTD	14.221	12.776	12.387	3.425	7.804	7.754	6.169	6.789	8.915625
WHOLE FOODS MARKET INC	14.343	13.359	13.695	5.984	14.516	12.527	7.604	7.295	11.66538
COSTCO WHOLESALE CORP	12.293	10.999	11.573	11.97	12.066	12.556	13.955	10.84	12.0315
MARUETSU INC	1.649	1.459	-43.124	-25.226	8.386	10.06	1.702	11.82	-2.909125
WALGREEN CO	16.359	16.339	16.583	17.543	17.306	18.383	16.761	13.954	16.6535
FAMILY MART CO LTD	9.357	9.346	8.044	8.438	9.143	8.971	8.624	7.558	8.685125
PRESIDENT CHAIN STORE CORP	21.97	26.665	21.204	24.073	23.915	22.286	21.399	21.453	22.37063
HARASHIN NARUS HLDGS CO LTD	5.665	4	5.968	6.617	6.033	7.226	4.893	6.232	5.829125
WALMART CHILE SA	7.907	6.698	1.154	7.778	7.656	9.363	3.375	-9.406	4.315625
MAXVALU NISHINIHON CO LTD	10.622	5.521	7.824	7.081	11.132	13.166	13.764	12.266	10.16575
CHUO GIORJI CO LTD	-1.058	1.461	2.815	2.547	5.208	-0.405	-8.761	2.824	0.578875
AX FOOD AB	36.917	32.158	26.423	29.982	35.207	36.292	32.625	30.095	31.96238
FOODCO HOLDING PJSC	6.624	8.481	41.895	48.562	23.603	7.166	13.701	9.545	19.94713
CONVENIENCE RETAIL ASIA LTD	20.581	15.13	15.134	15.186	14.187	11.939	11.597	11.566	14.415
KROGER CO	32.026	7.829	-2.825	21.822	22.649	24.033	24.131	1.449	16.38925
SIAM MAKRO PCL	10.519	10.785	11.873	12.857	13.991	15.573	19.631	17.482	14.08888
BOOKER GROUP PLC	-1.245.19	@NC	-53.774	-42.251	@NC	11.705	14.899	17.172	-216.406
CENCOSUD SA	8.507	8.941	6.999	8.296	9.493	12.256	6.87	4.427	8.223625
CPS CORP	4.867	4.179	3.188	4.862	-18.008	2.43	2.726	3.278	0.94025
ABON CO LTD	12.022	11.546	9.82	4.279	6.315	5.049	-0.336	3.699	6.54925
SAN-A CO LTD	14.453	13.421	12.24	10.386	10.252	10.539	9.395	8.826	11.189
JOHN LEWIS PARTNERSHIP PLC	2.777	3.987	4.358	6.743	6.56	8.274	13.557	6.25	6.56325
MARUYA CO LTD	3.509	2.945	0.576	-8.048	-36.991	-26.134	-18.02	-10.832	-11.6244
LAWSON INC	5.835	12.034	12.749	12.572	10.748	11.935	12.181	6.533	10.57338
METRO AG	10.716	11.92	17.451	9.79	15.679	13.637	14.296	6.656	12.51813
CP LOTUS CORP	15.92	9.124	-24.457	-193.259	@NC	@NC	-10.343	-174.656	-62.9452
DELHAIZE AMERICA INC	8.269	6.671	8.686	8.986	9.52	@NA	@NA	@NA	8.4264
HIPERMARCSA	-0.279	-4.338	-7.827	-6.789	-10.234	-46.919	24.969	2.648	-6.47113
CARREFOUR SUPERMARCHE SA	22.537	24.698	24.133	21.589	19.578	17.523	12.357	3.723	18.26725
TESCO PLC	14.518	13.845	15.168	16.844	17.837	17.977	16.703	15.943	16.10438
SAINSBURY (J) PLC	9.075	7.759	1.395	1.647	7.473	6.667	6.604	11.78	6.55
OLYMPIC CORP	5.855	4.955	-1.069	0.927	-11.254	0.304	1.407	0.427	0.194
BEBE STORES INC	14.669	9.575	13.816	19.905	18.08	15.315	12.982	2.75	13.3865
ITOCHU-SHOKUHIN CO LTD	9.331	7.726	7.528	4.849	8.016	4.605	3.532	6.61	6.524625
MASSMART HOLDINGS LTD	22.751	25.767	30.391	37.545	43.482	47.306	48.067	39.665	36.87175

ROIC sample data from Compustat for e-tailers and traditional retailers (2002-2009)

Retailers Firm	2002	2003	2004	2005	2006	2007	2008	2009Average	E-tailers Firm	2002	2003	2004	2005	2006	2007	2008	2009	2009Average
KROGER CO	9.647	2.556	-0.006	8.045	9.45	.10	9.491	0.54	0.09952E-02	INTERTICKET.COM LTD	55.105	27.172	16.905	4.706	-6.599	-19.236	0.595	1.9311
WALMART CHILE SA	5.575	4.307	-0.774	6.247	5.071	6.377	2.005	-4.915	3.107E-02	CRAVINGS PLC	@NA	65.677	7.272	-32.181	-6.160	-29.077	-91.218	-84.314
FAMILY MART CO LTD	6.06	6.065	7.565	6.076	6.715	8.591	8.835	7.011	3.131E-02	VIBRACOM INC	-36.103	-20.655	-1.631	-14.695	-67.356	-17.01	-10.611	10.072
MARUTSU INC	1.069	0.952	-27.011	-16.949	5.000	6.109	8.723	9.345	-1.576E-02	PETMED DIRECT INC	57.552	41.543	30.070	32.072	26.816	29.690	30.649	36.784
MARUZEN NIHON KO LTD	9.477	4.877	7.204	6.715	10.387	15.116	15.729	10.593	9.531E-02	DESTINATION INC	-5.767	4.969	-4.777	-.36	-71.599	11.875	1.725	-17.871
DOUGLAS HOLDING AG	-1.170.96	2.954.94	-53.774	-14.005	3.046	8.701	12.719	15.104	2.154E-02	DUCHI DE INTERNET GRUPPE	-.156	46.600	1.115	5.286	.632	-2.431	4.496	4.344
MARKS & SPENCER GROUP PLC	16.196	21.311	16.592	17.457	19.027	18.996	18.724	18.738	4.396E-02	CENTRO INC DETAILED INFORMATION	121.692	61.966	74.288	16.035	2.08	6.986	87.692	0.984
WALGREEN CO	15.881	15.080	15.955	17.009	17.000	18.003	14.983	11.79	1.581E-02	DENACOM LTD	-39.896	22.956	9.440	13.145	17.498	13.914	31.011	11.024
WALGREEN CO LTD	7.445	7.225	7.344	2.567	5.052	4.887	3.884	4.374	5.347E-02	NUTRISYSTEM INC	42.132	0.74	0.37	20.527	58.275	74.190	40.084	22.515
WHOLE FOODS MARKET INC	11.35	11.012	11.535	9.89	11.120	8.836	1.704	1.371	9.838E-02	DVD CLUB INC	-4.186	-11.177	-59.571	-30.092	-13.695	-11.921	-16.710	-7.306
COSTCO WHOLESALE CORP	9.795	8.848	9.039	10.814	11.515	9.013	11.044	8.696	1.007E-02	NEBUNET AG	6.848	8.401	0.372	0.520	2.843	2.619	16.705	2.387
CHUBO CORNICO LTD	0.967	1.368	2.889	2.448	5.014	0.883	9.045	2.356	0.695E-02	SOLFRIGHT ONLINE	10.227	14.435	11.327	0.520	2.843	1.008	7.452	11.189
FOOD DOO HOLDING PLC	4.515	0.180	5.276	13.527	2.059	0.489	11.045	0.14	1.0275	HOLLYWOOD MEDIA CORP	-10.221	-19.325	-24.109	-10.592	-15.528	-17.555	-27.656	-19.145
MARKS & SPENCER HOLDINGS LTD	4.761	2.018	4.548	5.37	4.576	5.176	3.412	4.435	4.097E-02	INTERPARK CORP	31.420	37.48	27.385	11.096	40.843	6.838	21.168	71.419
SHIN SEGAI IO PCL	10.519	10.725	11.875	12.257	13.991	15.573	19.691	17.18	1.107E-02	NEXTCOM INC	1.01	26.143	-4.495	2.336	-0.491	-4.485	-5.757	2.448
COMPANHIA BRASILEIRA DE DISTRIBUICAO GRUPO PAO DE ACUCAR SA	20.568	15.180	15.364	15.278	14.141	12.071	11.738	11.696	1.485E-02	NOVATEL INC	24.484	22.361	10.653	17.101	16.467	5.353	8.520	4.436
CENCOSUD SA	5.54	5.845	5.072	5.815	6.275	7.087	4.205	2.722	5.419E-02	LDIC COM	27.916	14.418	18.079	-25.962	-21.579	9.254	10.711	25.595
CP LOTUS CORP	17.887	7.078	-30.187	-11.111	-15.535	-30.986	-7.368	-13.350	-1.180E-01	MINERVA HOLDINGS CO LTD	-.000	37.162	.35.951	11.036	.77.36	17.171	0.287	0.200
MARU WACOO LTD	3.434	2.878	0.576	7.058	35.173	36.467	17.206	10.306	11.164E-02	NETFLIX INC	24.486	5.776	13.818	10.576	11.185	15.548	31.557	36.591
SAN A CO LTD	9.701	10.074	9.079	9.163	9.420	9.934	9.886	8.324	9.424E-02	NETWINEFAB	14.097	6.974	12.486	@INC	8.383	19.692	10.622	9.483
AVEDO AB	38.395	36.513	23.661	21.631	31.705	32.678	29.39	28.001	27.118E-02	UTEN INC	-10.765	-19.211	-30.689	6.901	0.598	9.812	-15.589	11.319
JOHN LEWIS PARTNERSHIP PLC	2.128	3.01	3.271	1.87	5.187	9.576	10.222	11.178	1.036E-02	STORE INC	3.532	1.322	6.101	2.776	-1.171	-2.112	-2.181	10.852
CARREFOUR SUPERMARCHE SA	9.055	11.007	11.285	10.639	10.288	9.521	9.137	1.912	2.715E-02	ESA CO LTD	-38.458	49.588	2.018	9.786	17.613	14.552	18.015	17.158
LAWSON INC	5.75	11.818	12.478	12.904	10.518	11.73	11.767	5.754	10.367E-02	ACCOUNTING CO LTD	-59.908	-5.717	30.367	9.696	-20.964	-18.438	6.9	6.857
TESCO PLC	8.675	8.987	10.068	11.087	13.784	11.883	8.513	8.806	10.237E-02	START TODAY CO LTD	0	8.989	36.181	36.506	27.534	24.157	29.769	36.963
DELHAIZE GROUPE SA	5.57	5.002	4.185	4.859	5.447	@NA	@NA	4.228	6.578E-02	CO LTD	17.949	11.345	-5.937	15.532	20.538	14.955	8.338	3.052
HYPERMARCAS	-0.28	-5.687	-6.792	-8.769	-7.725	-28.772	16.431	1.995	-1.575E-01	ADVERTISING INC	-10.792	5.969	36.52	18.248	11.19	18.755	20.125	16.573
MEDCHOI SHOKUHIN CO LTD	9.264	7.691	7.5	4.842	8.006	4.609	3.532	0.45	4.866E-02	INTERNET AG	6.093	25.237	49.095	110.673	102.544	51.228	-11.409	-12.528
MASSMART HOLDINGS LTD	19.298	22.163	26.982	33.837	33.407	39.664	43.3	37.282	3.169E-02	ASOS PLC	-9.257	20.457	24.300	27.143	28.849	31.692	30.932	32.079
SUPERMERCADOS LIMA SA	6.481	5.384	1.014	4.037	4.987	4.41	7.939	4.511E-02	ROW/CONTINENTAL GLOBAL INC	-.241481	.241481	4.147	6.921@NC		11.345	6.174	1.688	-.241481
METRO AG	4.618	4.696	7.277	4.402	7.407	7.302	7.462	3.007	5.823E-02	BLUE NILE INC	48.616	89.219	11.948	16.186	27.618	27.128	57.735	30.048
CPS CORP	3.552	2.851	2.464	3.524	12.099	1.093	2.405	2.75	0.885									
MEIJI CO LTD	1.955	1.407	1.391	1.961	2.618	2.279	-0.117	1.161	2.796									

SECTION V:

SOCIAL SCIENCES

Socio-cultural impacts of electronic media: A Case for Sakubva Suburb in Mutare.

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ABSTRACT

In this paper the authors explored the impact of electronic media on youths in Zimbabwe. The youths are exposed to a lot of media content from radio, television, internet and other Web 2.0 platforms. The socio-cultural impact that this content has on the youths' personality, behaviour and life style requires that they are inducted into media education skills. 71 youths from two high schools in Sakubva suburb of Mutare were sampled for the study. Questionnaires and Focus Group Discussions (FGDs) were used to obtain quantitative and qualitative data. It was found that the youth spent a considerable time on electronic media. This study also found that the youths got benefits such as educational value, promotion of research skills, development of social networking skills and others. The paper also found very little media education skills such as evaluation, criticism, discrimination and comparison that can be used to distinguish between the good and bad of electronic media. Recommendations to capitalise on the abundant use of, and interest on media by the youth were made to schools and the home, for educational and socio-cultural development.

Key Words: social-cultural, electronic, youths, media.

INTRODUCTION

The world's communications tools are fast changing. Print media in the form of books, magazines, and newspapers is rapidly being overtaken by electronic media. Electronic media is media that utilises electrical gadgets or electrochemical energy for an audience to access the content, (Ahn, 2011). The primary media sources include video, television, radio, multimedia presentations, telephone, cell phones, computers and other forms of digital media. The evolution of electronic media has also given rise to internet and social network sites (SNS). Ahn (2011) defines SNS as part of a suite of web applications also known as social media, which utilises Web 2.0 principles. The term Web 2.0 was coined by Tim O'Reilly (Ahn, 2011; Smith and Campbell 2012). Web 2.0

are websites that are designed to; rely on the participation of whole groups of users, aggregate and remix content from multiple sources and network users and content together (Ahn, 2011). Features of these social media platforms include Face book, YouTube, MySpace, Twitter, Google Play, Instagram and others. This study considered television, radio, cell phone, computers (desktops or laptops) and SNS all as electronic media.

There has been a high global awareness amongst the youths on the use of these tools; especially the internet and the cell-phones to access web 2.0 applications. On such platforms the youths are wall posting, providing status updates to reach others, profiling and texting messages to a network of friends on various content (Ahn, 2011; O'Keeffe and Clarke-Pearson, 2011). Although electronic media has its bad side, it is clear that it is the main way that is now being used to access reading material such as journal articles and books, chat with parents within and outside the country- especially with a sizeable population of Zimbabwe living outside the country. The instant relaying of information courtesy of these latest technological products and services make people aware of what is happening in no time. In this context, electronic media especially social media provides the 'fabric' that connects families and friends. This paper focuses on the impact that these platforms, together with television and radio, have had on today's youth. Its aim is to review theories and understanding around the use and influence of electronic media in urban socio-cultural settings. However the paper also takes note of the importance of the skills to distinguish the good from the bad of media content.

When young patrons browse the internet they are exposed to information from all kinds of sources. In most cases these youths cannot distinguish what is fact from what is fiction. To compound the situation they are not aware of how much influence the viewed content will have on their lives. Teaching them how to find trustworthy information on their own is an essential life skill as well as a research skill that should accompany their orientation in the homes and in school (Duncan et al, 2011). A lack of such guidance on media navigation skills may expose youths to many conflicting belief systems.

Theoretical framework

This study was influenced by the uses and gratification theory. The theory looks at what people use as media and the reasons for media use (Mabika, 2007; West and Turn, 2010; Larose et al 2001). According to LaRoseet al (2010), the uses and gratifications theory assumes that audiences actively seek out media in a goal directed way that which provides them with the means of gratifying a wide variety of needs. The uses and gratification theory, which guides this study, views the audience as

actively seeking specific types of media for the satisfaction or gratification of their personal needs. In addition, the theory suits this study because of its elasticity to include various types of electronic media. Gratification received from the varied media includes socialisation, entertainment, self seeking and information, and the relaxation motive. Although the theory is criticised for its failure to account for internet usage on some other variables that motivate human behaviour (Kaye, 1998; Perse and Greenberg-Dunn,1998), LaRose et al, (2010) assert that the uses and gratification theory "…has a 30 year tradition that offers many insights into communication behaviour". (p 408)

Literature Review

Several researches have documented the benefits of electronic media (O'Keeffe and Clarke-Pearson 2011; Kirkorian et al 2008; Sadki, 2012). Among the benefits, O'Keeffe and Clarke-Pearson, (2011) identify the following:

(i). Enhanced learning opportunity

(ii). Opportunities for individual and collective creativity through development and sharing of

(iii). Growth of ideas from the creation of blogs, podcasts, videos and gamming sites

(iv). Fostering individual identity

(v). Expansion of one's online connections through shared interest to include others from diverse backgrounds.

Professionals in collaboration (Kirkorian,et al, 2008) argue that youths also benefit educationally from electronic media such as educational television. Quite recently, electronic media, especially social media has been used by youth to promote and enforce civic rights. The onset of the Arab uprisings that occurred in Arab countries such as Egypt, Libya, Syria and others demonstrated the power of social media (Sadki, 2012). According to a UNICEF (2010) document it is through media such as radio, television and print media that issues of poverty, education and disease, which affects the youth of Zimbabwe are heard and understood by people at different levels in society. However, the same media can promote violence and a poor sense of identity in youths, stifle creativity and cause trauma in young children. According to a Committee on Public Education (AAP, 1999) of the American Academy of Paediatrics (AAP) the average American child or adolescent spent close to 21 hours per week viewing television. Lairds (Laird, 2012) says Face bookusers in India, France, the Unites Kingdom, Australia, New Zealand and Singapore all spend an average of more than 20 minutes on site every day. This communication tools waste time (Kain, 2012). Further, time spent on media often displaces involvement in creative and active social pursuits (AAP, 1999).

While a great deal of research has been done on the effects of media on today's youths elsewhere, very little has been done in Zimbabwe. Mabika's study (Mabika, 2007) focused on globalisation and the impact of local content policy and youth culture in Zimbabwe. The study found out that television has ideological and hegemonic functions. The youths' life styles in the study were found to be influenced on issues of dressing, musical tastes and language resulting in threats of weakening long established local cultures. However, Mabika's study (Mabika, 2012) did not extend to the effects of quite recent media like the SNS on the youths in Zimbabwe. One youth made the following observation in an article in the Manica Post (Manica Post, 04/2013.

> We watch a lot of television nowadays and are addicted to information communication technology. This tends to impair our definitions of joy and corrupts our moral values and personalities. (p13)

While the comments point to awareness in some youths in Zimbabwe about the negative impact of media, further research is required to ascertain how wide spread this awareness is.

Research on the need for media education has been done in other countries, especially the developed world (Hunston et al 1992; Singer et al 1980). Media education is defined as the educational and intellectual skills required interpreting information from print or electronic media. Some authorities (Huston et al 1992; Singer et al 1980) argue that the term can be used interchangeably with media literacy. Examples of such media literacy skills include the ability to evaluate, critique, discriminate, compare and analyse information coming from media tools such as radio, newspapers, television, internet and others.(Perse and Greenberg-Dunn 1998;Kirkirion et al 2008) According to the AAP (AAP, 1999) media education has the potential to reduce the harmful effects of media because a media educated person has skills to limit use of media, make positive media choices, select creative alternatives to media consumption, and develop critical thinking and viewing skills. The researchers in this study noted that by understanding and supporting media education, parents and teachers can play an important role in reducing the risks of exposure to mass media and its impact to the youths in Zimbabwe.

Statement of the Problem

The advance in technology that has caught today's society has brought with it several benefits in the various spheres of the youths' life. The perceived benefits such as enhanced educational value, promotion of social skills and others have resulted in national development for most countries. However, technology such as electronic media could have some negative impacts on today's youth that are invisible to the ordinary person. These negative effects of electronic media may harm the

youths more if they (the youths) are not inducted on the utility of media literacy skills. Specifically the study was guided by the following question: What are the impacts of electronic media and the prevalence of media literacy skills on/in youths in Sakubva suburb of Mutare.

OBJECTIVES

This study sought to investigate the socio- cultural impact of electronic media on youth in Mutare Urban and their level of exposure to media education. In order to guide the study the following objectives were pursued:

1) To identify the types of electronic media commonly used by the youths in Sakubva suburb of Mutare.
2) To establish the amount of space/time that electronic media occupies in the lives of the youth in Sakubva suburb of Mutare.
3) To identify the content/ substance of electronic media commonly used by the youths in Sakubva suburb of Mutare.
4) To investigate the media education skills prevalent in the youths.
5) To explore the perceived socio-cultural impact of electronic media on the youths in Sakubva suburb of Mutare.

METHODOLOGY

A triangulation mixed-methods approach was used for the study. In this approach both qualitative and quantitative methods are used to interpret data. Onwuegbuzie and Turner (Onwuegbuzie and Turner, 2007) define it as an approach employing quantitative research assessing magnitude and frequency of constructs and rigorous qualitative research exploring the meaning and understanding of constructs. The approach was preferred for the study because it provided the researchers with a dialectical stance that bridge the positivist and social constructivist world views. (Greene, 2007). It was also utilised to provide a complete picture of the issues under study. However, the approach presents challenges where and when there is a clash of world views, especially when the researchers are not trained in the use of the approach.

Participants

Convenience sampling was used to draw the 71 youths who participated in the study. These were mainly high school students (age range 13-20) from two secondary schools from Mutare urban. Of the respondents 46% were female and 54% were male, 38% were within the 13-15 age group and 62% were in 16-20 category, 85% were living in the high density suburb and 15% in the medium-

low density suburbs. Furthermore, the majority of them (82%) were living with their parents while 18% stayed with a guardian.

Procedure

Questionnaires were pilot tested with an initial 10 respondents. This was done to achieve questionnaire reliability. The questionnaire was cleared of most ambiguous and vague statements, resulting in an instrument that was user-friendly for the wide range of age group. The pilot tested questionnaire was later administered on the cohort group. The questionnaire had both closed and open-ended questions. After the questionnaire was completed, 7 and 10 respondents were conveniently selected from the13-15 and 16-20 age groups respectively for some focus group discussions (FGD). The three researchers were involved in both FGDs. This led to trustworthiness of the qualitative data generated in the FGDs, because of interviewer corroboration.

Ethical Considerations

Permission to carry out research with the respondents was sought from the Ministry of Education, Sport, Arts and Culture (MoESAC) and the school authorities. The consent of the participants was also sought after explaining to them the research purpose and process. No real names were used in writing the research report in order to protect the participants' right to anonymity.

Analysis

Questionnaire (closed questions) data was analysed using descriptive statistics, graphs and tables. Data generated from open ended questions of the questionnaire and FGDs was analysed qualitatively. Sorting and sifting of generated data gave rise to patterns and codes that led to emergent themes. Excerpts and direct quotes (verbatim) were used to present evidence for the themes that emerged from the qualitative data.

RESULTS

Findings of the study indicate a high level of use of electronic media gadgets among the youth with the cell phone having the highest frequency (82%) of use. Table 1.0 below shows the frequency of use:

Table 1.0: Frequency of use of electronic media gadgets among youths in Mutare urban. N=71

Electronic media gadget	Frequency of use (%)
Cell phone	82
Computers/ laptops	55
Television	63
Radio	58
iPod	NIL

90% of the respondents had access to internet with the majority of these reporting accessing the internet at school, and a smaller percentage 13% accessing the internet from their cell-phones or at internet cafes. Cell-phones had the least frequency (21%) of use to access the internet, while computers/ laptops were used more (79%).

It also emerged that youth spent quite a considerable time on electronic gadgets with recorded mean of 6 hours per individual per day spent on TV, cell-phone, radio or internet. The graph below shows the trend.

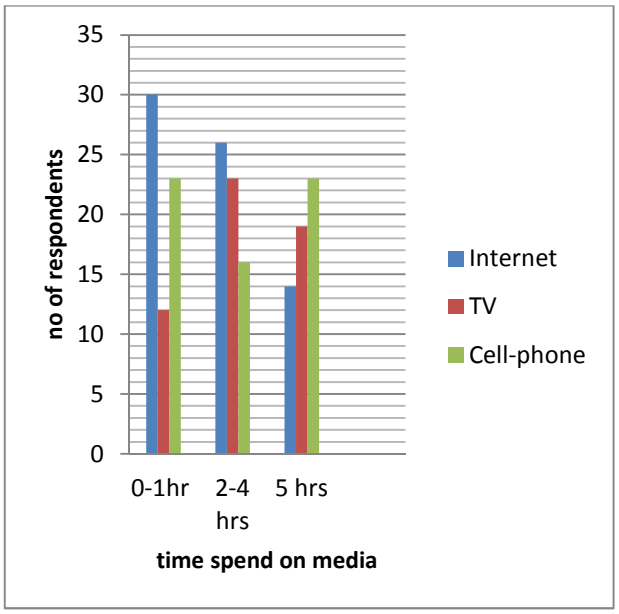

Figure 1.0; Graph showing time spent by respondents on electronic media gadgets. N=71

Data generated by the FGDs corroborated with what the graph (above) indicates. In the discussions the youths admitted to spending a lot of time on electronic media. One of the youths said:

> *Kazhinjindinoonamamovies.Kana movie iri 3hrs ndinodzipedza.Kana yaperandinengendakudamagames, nekutipanengepasinabasa.*

Translated: Most of the time I watch movies. If a movie is 3 hrs, I spent the 3 hours watching it. If it is finished l play games because usually there is nothing to do. The youths also engaged in multiple accesses. Multiple accesses mean accessing more than one type of media per day.

The study's finding also recorded diversity in the type of content accessed by the youth from various media. While the respondents reported use of TV and radio to access local news and music, there was a high prevalence of educational content, SNS content and videos accessed through the internet. The type of SNS accessed was used in the study to determine the type of content the youths preferred as shown below.

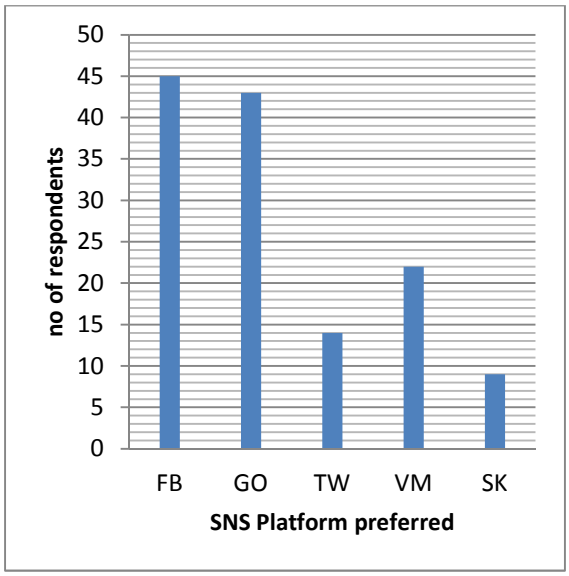

Figure 2.0: Bar graph showing favourite SNS platforms for the youths. N=71

Key

FB= Face book; GO=Google; TW= Twitter; VM= Video/Movies; SK= Skype

The graph shows that Face book was accessed most by the majority of respondents. Face book provided the youth with opportunity to socialize and network with friends, send and view profiles and news updates. In the FGD the respondents reported accessing educational information, research work, cultural knowledge, business and technological content. The following excerpts from open

ended questions of the questionnaire exemplify what the youth got as content from electronic media:

> *I get information for my academic subjects. I Google on birth rate in USA so as to get information concerningGeography.*
>
> *Information on cultural diversity, news updates and anything happen in society.*
>
> *You get information on how to make your girlfriend to love you like Jeee -eee!!!!*

The youths in the study acknowledged that electronic media was having an effect on their culture. The third quote suggests that some youths also accessed sexually explicit content such as pornography.

Further findings of the study show a low level of awareness on skills to evaluate, select, analyse and utilised media platforms, especially the TV and internet. The majority youths indicated that they had not been taught at home or at school on skills to evaluate media content. The following skills were identified in the study as key to media education:

1. Skills to evaluate web sites.

2. Limit use of media.

3. Detect fact or fiction (critical views)

4. Switch off or move away from the website, when bad content appears.

5. Make a choice on media consumption.

The graph in figure 3.0 shows the number of respondents that had been educated on the various skills media literacy education, at home or at school.

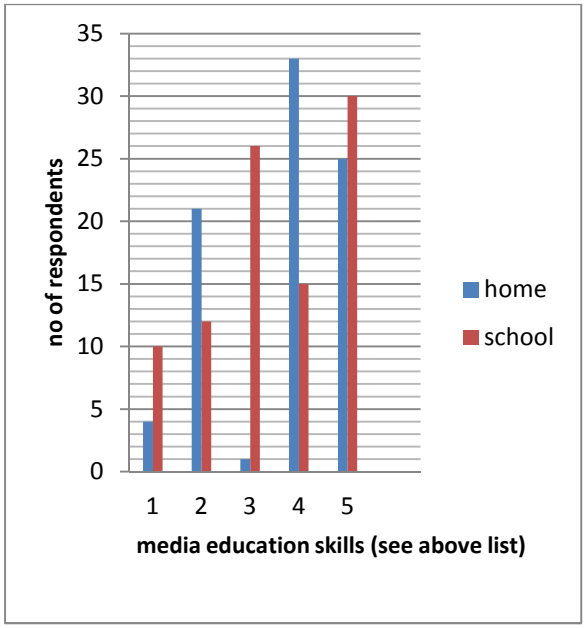

Figure 3.0: Bar graph showing favourite SNS platforms for the youths. N=71

The graph above shows that the respondents received very little skills to evaluate web sites (skill number 1), with only 4 out 71 (0.06%) and 10 out 71 (14%) reporting to have gotten the skill from the home and school respectively. The home seemed to be performing fairly well in asking the youths to switch off (skill number 4) whenever 'bad content' appeared on the TV screen.

In the study it also emerged that electronic media had significant influence on the youths. The majority (56%) of the youths thought that media had negative influence on their lives. While benefits like educational knowledge, interactions and social networking, entertainment and cultural diversification were recorded as positive gains on the other hand personality changes, addiction to internet, crime, time wasting and addiction to sexually explicit content were viewed as causing negative impacts. The following direct quotes from the open-ended section of the study's questionnaire and FGDs data exemplify the scenario:

> *Some of us spend more time on TV and internet than on books. Hence lower pass rates....*
>
> *It offers information that sometimes teachers can't offer and get knowledge of what is happening in our country.*
>
> *Because some people of my age are now learning bad things e.g. pornography and getting into Satanism.*
>
> *Watching pornography give me negative thoughts.*

Information is not good sometimes erode our culture and beliefs.

Furthermore, the youths also reported imitating some behaviour, hair style, dress language and tone of celebrities found on videos and TV.

DISCUSSION

The results of the study confirmed what the uses and gratification theory says. The youths in the study used specific media and content to satisfy their basic social and educational needs. The findings of the study confirmed what Mabika, 2007) and La Rose et al (2001) found, that youths selected only specific elements of the media which suit their backgrounds and gratify their individual needs. The youths in the current study showed preference to the use of cell-phone, computers, TV and video. A preponderate use of the internet and SNS platforms such as Face book was discerned. This was also confirmed in similar studies that have looked at the use of social media by youths and adolescence (Smith and Campbell 2012; O, Keeffe and Clarke-Pearson, 2011; Kirkorian et al 2008).

The time spend on electronic media by the youth is generally a worry for most adults, teachers and parents. Observations made elsewhere (Laird, 2012; Manica Post, 04/2012) on the amount of time youths spent on electronic media was also confirmed in the current study. The amount of time spent watching a movie on television has a bearing on the youths' study time. Time spent can never be regained. The youth period is a time when most of these young ones are supposed to learn productive adult behaviour such as socialising with the family and work colleagues. A lot of time spent on the electronic media is detrimental to this virtue of productive behaviour. This is because the time that should be spent on face to face socialisation with colleagues, and academic study is inadvertently spent on the face book. This is not to suggest that electronic media only has negative impacts but it also has several benefits.

Literature (Ahn, 2011; Sadki, 2012) and research (Smith and Campbell, 2012; Mabika, 2007; Fotheringham and Alder, 2012) have clearly outlined the benefits of such media. Similar benefits such as development of research skills, adding new frontiers of knowledge, developing relationships and cultivating life skills and others were established in the current study. Exposure to cultural diversity through SNS platforms enabled the youths to gain some life skills such as tolerance. However, some (Mabika, 2007) authorities view this diversity as eroding already existing cultures. Some of the respondents professed the truth of this notion of cultural erosion and the spread of Satanist beliefs in the interviews. The current researchers conjectured that reducing negative impacts and tapping on such aforementioned benefits would carry our youths in Zimbabwe

to greater heights. For instance, if schools were to make use of the teenagers' current tools of communication, that is the SNS, and utilise Web 2.0 principles to establish computer managed learning platforms (CMLP), improved learning would be achieved. Fortheringham and Alder confirmed in their research (Fotheringham and Alder, 2012) that mobile technologies can be used in schools (learning institutions) to aid students' welfare and learning processes.

Negative impacts on youths' social life were also found in this study. Mabika confirmed the same results with youths in Mbare, Zimbabwe (Mabika, 2007). The youths' life styles were influenced in issues of dress styles, musical tastes, behaviour (personality) and other influences. Mabika argued that this tended to affect the youth social cultures. This study made the observations that most of the negative impacts tended to emanate from the content of what was watched, surfed or listened to. Violence, addiction and viewing of sexually explicit content often led to e-crime like online harassment (cyber bullying) and hacking (O'Keeffe and Clarke-Pearson, 2011). Similarly an overdose of such content gave youths in this study some negative thoughts. The low level of media literacy education that was established by the study makes the situation worse. A youth endowed with skills to evaluate media, detecting good and bad websites, content, videos and other information is better equipped to use the internet and reduces their risk of exposure to hazardous content from electronic media (AAP, 1999).

This study however had its own limitations. The study's sample made up of youths in the 13-20 years category was mainly drawn from high school students. That does not fully represent the youth category, some of whom are now school leavers, some in streets (as school drop outs) and other such places where youths can be found. In addition, the seventy one people that made the sample of the study may not have been representative enough of the trends in the use of internet in Sakubva. The research area for the study might have been too wide. Focus on the whole range of electronic media was a bit problematic methodologically. The study could have focused on one area such as social media. The current researchers propose that future research can focus on a detailed study on the socio- cultural impacts of social media on a wider range of participants (the youths, parents and teachers).

CONCLUSION

The study sought to investigate the socio-cultural impact of electronic media and the prevalence of media education on youths in Mutare Urban. A sample of 71 youths participated in the study. Their views were solicited using a questionnaire and some focus group discussions (FGDs). The study found out:

(i). A high level of use of electronic media gadgets such as cell-phone, television and social media, with 79% on internet use and 63% on face book.

(ii). That the youth spent quite a considerable time on electronic gadgets with a recorded mean of 6 hours per individual per day spent on TV, cell-phone, radio or internet. The time spent on media and interaction with the media was influencing youths to adopt certain behaviours, languages, dress codes and personalities from electronic media content. This tended to result into adoption of foreign cultures.

(iii). That documented benefits of media such as its educational value, development of social networking skills and others also accrued to the youth in the current study. The youths, for instance, were using the internet for their studies at school. The same was found for the negative impacts-addiction to internet, change of behaviour, erosion of some cultural beliefs and negative thoughts resulting from watching violent videos and sexually explicitly content.

(iv). A low level of media education skills amongst the youths. The youths had very few skills to evaluate web sites, limit use of media, make a choice on media consumption and use critical thinking to distinguish fact from fiction.

The researchers argued that the amount of time spent on electronic media was very high and this compromised on the youths' engagement in productive behaviour such as academic study and face-to-face socialisation with the family and friends. Furthermore, it was also claimed that a lack of skills to evaluate and analyse media resulted in greater risks and harm caused by electronic media content. The use of today's electronic media gadgets should be accompanied with deliberate efforts to induct the youth with comprehensive media education skills in order to develop a positive youth culture.

RECOMMENDATIONS

In the light of what was found in this study the following recommendations are made:

(i) Schools in Zimbabwe can capitalise on the youths' interest in electronic media especially SNS and mobile technologies and use these as tools to aid learning.

(ii) The youths should; carefully plan when to use electronic media, learn the skills to choose which media, which website to use and at what time, and analyse media content to detect fact, fiction, propaganda and useful information.

(iii) Parents and educators should really begin to think about the possibilities of imparting media literacy education in the family circle and curriculum respectively.

If the recommendations above are pursued the negative impacts of electronic media on Zimbabwean youths may be turned into vast opportunities to develop a positive youth culture, and a better society.

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The socio-economic impact of Vocational Education Skills Training Centres among the Bulawayo youth during the period 2008 to 2012: a case study of Lobengula and Sizinda training centres

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ABSTRACT

The study focused on the socio-economic impact of Vocational Education Skills Training Centres among the youth in Bulawayo, particularly the period 2008 to 2012 mainly characterised by socio-economic and political crisis watershed. A case study design was adopted focussing on Lobengula and Sizinda Training Centres. A population of two principals, nine lecturers and fifty-one youths were purposively sampled from the two institutions. As much as the vocational skills training centres have aided in manpower skills development for employers who are primarily concerned with job-related training, there has been an urgent need to equip youth with the trade skills that include carpentry, catering, metal fabrication and hairdressing. The results revealed that the aforementioned skills have emerged critical in youth self-employment in the wake of the economic crisis in Zimbabwe. The study recommended an increase in the provision of formal vocational education skills training for the long-term development process in Zimbabwe.

Key Words: vocational, education, socioeconomic, skills, training

INTRODUCTION

The importance of education could be generally argued to be well known to most people. It starts with acquiring basic general knowledge and then depending on further education it narrows down to educating in more specific areas of a student's choice. Besides having personal benefits for the student, and in this case the youth, education also has a strong economic and social impact. The significance of education is immense not only on personal level but on a larger scale as well. An educated worker who knows their job well is certainly a valuable asset to every company or organisation and that way to an economy and a society of a country (1).

According to the International Labour Organisation (ILO) estimates, of the total 200 million unemployed worldwide, 75 million or around 40 percent are young people. Between 2007 and 2010, youth unemployment increased by 5.1 million and in 2012 four out of ten unemployed was a

young woman or man (2). A report from the 2010 Africa Economic Outlook revealed that more than 60 percent of Africa's population is under the age of 25 and this is expected to increase to 75 percent by 2015. Like all countries in the Southern Africa region, Zimbabwe is a very youthful nation in terms of its demography. The implications of the demographic profile are that a youthful population presents problems in terms of the provision of social services such as education and health as well as employment. Conversely, Zimbabwe's youthful population also presents opportunities for progress, hence the need to channel their energy towards positive and productive paths (3).

The issue of youth skills training dates back to the period just after independence, as a way of curbing the youth unemployment rate in Zimbabwe. Almost immediately after gaining independence in April 1980, the government embarked on a programme to establish a network of youth centres throughout the country. These were residential work training programmes focussed chiefly on rural youth and work in rural areas. They were organised primarily for the unschooled youth where literacy and trade skills could be learned, providing unemployed youth with skills needed in the locality (4). The foregoing observation gives the background to the starting of the vocational skills training centres. Much national attention and concern has been generated over the issue of youth unemployment (5). The two vocational training centres under discussion fall under the Ministry of Youth Development, Indigenisation and Empowerment. The broad mandate of the Ministry is to spearhead the formulation and implementation of youth development policies that strive to empower the youth to be self-employed and to support their families while at the same time building their country (6). The Ministry established skills development as its priority within the National Youth Policy. In this light at least 45 Vocational Training Centres for training young people on life skills have been established across the country. The Vocational Training Centres are a hub of the Integrated Skills Outreach Programme which reaches out to communities imparting livelihood skills to the youth (7).

As high unemployment rates sweep the nation it seems appropriate to assess the role of youth training centres, highlighting current trends and underlying issues vis-a-vis skills training for youth. It is in this light that the study adopted the human capital theory mostly responsible for the wholesome adoption of education and development policies. Based upon the work of Schultz (1971), Sakamota and Powers (1995), Psacharopoulos and Woodhall (1997), human capital theory emphasises the role of education, particularly the development of skills, as enhancing the productive capacities of individuals (8). Productivity of the youth in this case has been directly equated to the educational skills acquired from their training centres. The theory also suggests that

education or training raises the productivity of workers by imparting useful knowledge and skills hence raising workers' future income by increasing their lifetime earnings (9). It is widely accepted that education creates improved citizens and helps to upgrade the general standard of living in a society. Therefore, positive social change is likely to be associated with the production of qualitative citizenry. Despite the criticism levelled against the theory, for example, that at individual level, it has become controversial whether or to what extent education or other forms of human investments are directly related to improvement in occupation and income, the theory remains applicable in the analysis of the socio-economic assessment of educational impact of training institutions vis-a-vis the curricula offered (10).

The idea behind the training has been to equip the young people with basic technology and skills which will enable them to either go back into their communities as better skilled personnel in their various areas of training, or to start business entities of their own as entrepreneurs. High unemployment rate of the youth in Bulawayo has posed serious socio-economic problems such as crime, prostitution, drug addiction and alcoholism, among other social ills. The closure of companies in the province has forced some youth to look for jobs in order to take care of their parents who have been affected by company closure. Most Bulawayo companies have relocated to Harare and that has increased people's suffering. It is also acknowledged that for the youth to engage in informal sector activities, they need some skills, which the academic curriculum they went through was not able to impart to them, the skills required would include both technical and entrepreneurial skills (11). The significant growth in graduates coupled with low economic growth has increased competition in the job market to the point where academic qualifications no longer guarantee any employment. This trend has made it apparent that there is an urgent need for the re-orientation of the education and training systems from its current academic thrust towards the acquisition of practical vocational skills. Curricula should be redefined so as to meet the specific needs of the informal and small-scale sectors as well as identifying and developing talents (12).

The socio-economic situation in Zimbabwe during the period under study has been characterised by the slow growth in the economy, rising unemployment, difficulties associated with the protection of basic social services in the face of a changing economic environment and the devastating HIV/AIDS pandemic. The foregoing characteristics have posed great development challenges for all Zimbabweans. However, the magnitude and implications of these problems have been more severe for the youth. The youth population lacks various basic opportunities for their development (13). In the face of diminishing employment opportunities in the formal sector the informal sector has remained the most viable for offering employment opportunities and economic growth. It is

against this background that the study has been carried out. In terms of employment growth, over the years the economy has not experienced any real growth. The annual estimated annual growth rate of 5 per cent of GDP has never been achieved. The absence of economic growth has had a negative impact on employment growth. This scenario has added to the already swelled unemployment problems experienced by school leavers.

As at 2010, only 0.9 million people were recorded as being in formal employment (14). The level of unemployment such as we have experienced, dooms the country to slow economic growth and the majority into poverty. In the light of the economic meltdown that had beset the country, it could be argued that to its credit, the coalition government has stabilised the economy and registered decent recovery. With the unemployment figures still quite high, it is a shocking abdication that the economic agenda has not previously addressed or focussed on how to create new jobs or formalise the informal sector (second economy) in which a significant proportion of economic activity appears to be taking place. The actual jobs created between 2008 and 2012 fell far too short at a time when more and more workers were being retrenched from both the private and public sectors. The employment and productivity solutions for many therefore lie in the informal sector and Small and Medium Enterprises (SMEs) that constitute a non-formal sector that provides chances of self-employment, practical skills and opportunities for work experience in the labour market (15). They need some basic skills to be able to participate effectively in these sectors (16) and it is against such a background that this study has been undertaken.

OBJECTIVES

The objectives of the study were:

- To ascertain the extent to which the youth in Bulawayo have had on opportunity to acquire skills for employment,
- To assess if Lobengula and Sizinda skills training centres have provided goods and services needed in the suburbs they are located,
- To measure human productivity potential in Zimbabwean youth through the provision of skills for self-employment,
- To make recommendations to Government and other stakeholders towards the improvement of the skills training programme.

METHODOLOGY

A case study design was adopted focussing particularly on the two Vocational Training Centres, Lobengula and Sizinda. These Centres are located in the suburbs that the institutions are named after. A case study design was adopted for its capacity in enabling the researcher to build a Gestalt (a whole) about the single-system based on various data sources (17). It was useful in soliciting views on people's experiences of making adjustments in the wake of an economic crisis that has beset Zimbabwe for a long time. Most of the data used was largely descriptive and the same method was followed in the analysis of the findings drawn from the questionnaires, interviews and observations regarding programmes offered; the enrolment patterns and opportunities for graduates.

In ensuring validity of data collected, the principals of the institutions were chosen for their construct credibility as heads of the institutions. It was hypothesised that they would answer questions without hesitation as a valid measure of authority on questions regarding enrolment and training support given to students in and out of training institutions. The data collected from principals was then triangulated with responses from tutors and students alike. The main reason for applying triangulation was to increase the reliability and validity of observations, analyses and findings. A representative sample was drawn from the population of students who are studying and those who have finished as a way of ensuring external validity. In order to address random errors such as subject fatigue, the researcher distributed questionnaires to the respondents and left them to fill at their convenience of which they were collected in two days.

A formal self-administered questionnaire was used in data collection. Use of a questionnaire facilitated non-interference of the researcher to the responses given. The questionnaire instrument was also chosen because of its accommodative nature in the use of closed- and open-ended questions. The nature of the research topic based on the socio-economic impact of skills training centres meant that open-ended questions had to be incorporated particularly in encouraging respondents to express attitudes or opinions in their own words. A semi-structured interview approach was chosen for its question-and-answer type of conversation that gave immediate answers to some questions that were otherwise insufficiently answered in the questionnaire. It also allowed for follow-up questions on the graduates life seeing that the socio-economic impact of the skills is a diverse exploration. The short time within which the research had to be carried out made the use of interview method more convenient in influencing the pace and amount of time required to gather data. Note-taking was done during the interview. A face-to-face situation between the researcher and the subject(s) necessitated observation. The socio-temporal contexts were noted, that is, students workshops, practical demonstrations in class and the materials used. Use of the

observations came handy in enhancing interview as a method since the researcher could ask questions regarding, for example, the availability of machinery and consumables for students practical.

At some stage of the interview and questionnaire all respondents were asked to furnish both qualitative and quantitative information about the training courses, facilities and instructors, courses offered, total enrolments and students characteristics, and the impact of concerned Ministry and other government policies and regulations. Fifty one students including graduates were purposively sampled for the study as per their courses of study. In addition, nine lecturers were sampled as per the given courses from the two institutions, including the two principals from the institutions under study. Questions about the turnover and profitability of each centre were avoided because respondents were obviously wary about disclosing such financially sensitive information.

Given the limited time and resources available, this study has concentrated on obtaining an overview of the activities of a representative sample of registered vocational training centres located in Bulawayo Province. It is also against this background that these institutions were purposively sampled because of their involvement in vocational education within the high density suburbs where most youths/ school leavers are found. All respondents were assured of strict confidentiality and for this reason the identities of the respondents cannot be revealed. The questionnaire also bore a statement of consent to this effect.

FINDINGS

Three sets of questionnaires were prepared and distributed to three categories of respondents from the two case study institutions, Sizinda Vocational Training Centre and Lobengula Vocational Training Centre. The categories included two Principals of institutions, Lecturers or Instructors and the trainees or graduates drawn from the various courses studied in each institution. Content analysis, which is a systematic analysis of written and verbal responses gathered during the research, was done following the framework of categories established in the questionnaires and the interviews conducted with the Principals, Lecturers and graduates alike.

As a point of departure Principals of institutions were asked to answer to their institutions' responsibilities. It emerged from the responses that responsibilities included primarily to train entrepreneurs by way of empowering youth with skills in the wake of high rate of unemployment. At an estimated 80 to 85 per cent, Zimbabwe's unemployment rate has been argued to be one of the highest in the SADC region where average unemployment was 24.9 percent in 2011 (18). Unemployment and a nation's Gross Domestic Product (GDP) are some of the strongest indicators

of how well the economy of a country is performing. The idea is based on an empirical relationship referred to as Okun's law which essentially associates the growth rate on real GDP to changes in the unemployment rate observed around the same time (19). Principals also serve in staff administration, funds management and coordination of exams and institution ceremonies such as graduation and award of certificates. The responses revealed that the institutions have requisite staff in place with clearly articulated responsibilities that could be utilised to better the outcomes. The administrators showed to be people who have had vast experience that ranged from 5 to 10 years thereby covering the period under study (2008 to 2012) and making them relevant respondents to the transitions that have taken place over the years in terms of youth training and graduate employment prospects.

The principals concurred in their institutions' mandate which they summarised as earmarked towards training and equipping youths with technical and vocational skills for self- sustenance and job creation. It appears that since these institutions are being run by the Ministry of Youth Development, Indigenisation and Empowerment, their mandate is drawn from the government's mission through the Ministry, that is, empowerment of young women and men so that they can realise their full potential as individuals, as members of communities, political and social action groups, and youth organisations and as key to development of Zimbabwe (20). This question was followed up with an inquiry on the nature of vocational uptake among the youth in the period 2008 to 2012 characterised by economic recession wherein the youth have been the greatest number of victims. At Sizinda Vocational Training Centre (SVTC), from year 2008, most females have been opting for catering and hairdressing and males opting for carpentry and electronics. Lobengula Vocational Training Centre (LVTC) revealed that they train at least 300 youths a year, mostly females, with males constituting only a quarter of the total graduates. The gender discrepancies were mentioned and noted from both institutions. One reason cited was that most male school leavers in the community did not seem to value the training(s) and instead opted to cross the borders to neighbouring Botswana and South Africa. Some even abandoned their studies midstream as they could not cope with the fees escalation due to the then plummeting Zimbabwean dollar. An upward trend in enrolment was noted at the introduction of the multicurrency system although a few could afford because the foreign currency had become scarce. Notably, most of the graduates and trainees come from the poor families and that state of affairs made them face challenges in fees payment.

Gender analysis of the uptake of courses has yielded some important lessons for this study and policy frameworks. These lessons emanate primarily from years of attempting to formalise analytical constructs that place the well-being of men and women, as well as girls and boys,

centrally in multidisciplinary settings. This seems to echo the fundamental objectives of sustainable livelihood and sustainable human development concepts (21). The responsible Ministry and institutions under study should realise that young women face higher unemployment rates compared to young men as evidenced by the increased numbers of females to males in the two institutions. Secondary sources from International Labour Organisation (ILO) indicate that out of the 97 economies considered in a recent global study, Zimbabwe included, female unemployment rate was higher than male unemployment rate in 62 economies (22). According to the Zimbabwe Population Census Results, of the August 2012 population which stands at 12.9 million, 6,234, 931 were males and 6,738,877 were females. The population figures also revealed that there were 93 men for every 100 women in the country (23). Statistical revelation shown in the foregoing discussion reveals that more has to be done in terms of investing in the empowerment of the girl child and successively women in the country, both in terms of education and creation of relevant skills for (self) employment opportunities. The government and relevant non-governmental organisations should consider channelling more of their resources in the promotion of gender equity in all spheres of socio-economic development.

The outcome of the training was also seen as critical in measuring the socio-economic impact of vocational centres under study. Principals were requested to refer to the number of students who enrolled and those that graduated at the centres. The results revealed that at Lobengula Vocational Training Centre, 90 per cent of the students they trained during 2008 to 2012 graduated with only a few dropouts. Reasons for high graduates were that most of the students are employed after doing attachment. At least 30 per cent of them were said to start their own business with the support of the training centre equipment. Suppressed resource availability had strangled the procurement of equipment by the graduates hence they depended largely on availed institution equipment for their small jobs in the community. This seemed to hold for carpentry and joinery graduates/ trainees; welding; dressmaking and electronics (in the case of Sizinda Training Centre).

Employment outcome of the training in terms of the students' fate after training was also investigated. The Principals revealed that most of their trainees and graduates do not have equipment to start their own business; hence the institution(s) accommodate them at the training centres when they get some projects to do. Lack of machinery was cited as having made them not to be self-dependent. One of the principals said that most trainees have been absorbed in formal employment especially those trained in catering, carpentry and electronics. Those trained in hairdressing find it easy to engage in self-employment as they can operate from home and they request their clients to bring all consumables, be it braids or chemicals. It is apparent from the

findings that what youth need to improve their chances of (self) employment are practical skills and opportunities for work experience in the labour market. Several initiatives undertaken to deal with the problem of youth unemployment suffer from lack of coordination at the national level, inadequate funding and a business environment that is not enabling, with high inflation and high interest rates (24). The foregoing argument has been amplified by The Youth Summit findings that majority of the developing economies lack the infrastructure to empower youth engaged in the informal sector and bring them into the mainstream economy (25).

The breakdown in terms of the courses attended by the trainees or graduates showed the averages per institution per year as illustrated in Table 1.

Table 1: The Courses Attended by Trainees/ Graduates per Institution per Year

Course	Institution	No. Per Year 2008 to 2011	2012 Nov Enrolment
1. Hairdressing	Lobengula Sizinda	+120 +150	7 25
2. Hotel&Catering	Lobengula Sizinda	+150 +170	22 20
3. Home Decor	Lobengula	+180	18
4. Carpentry& Joinery	Lobengula Sizinda	+48 +50	10 10
5. Metal Fabrication/ Welding	Lobengula Sizinda	+70 NIL	4 NIL
6. Electronics	Sizinda	+15	5

(Own Survey, 2012)

Statistical data gathered for various courses reflected that more female students than males prefer to take up courses in hairdressing, hotel and catering and home decor, while the numbers decreased for courses taken by male students.

For precise analysis of the impact of the vocational skills, institutions were asked to comment on their follow-up strategies that they have set up. Both institutions revealed that students leave their details after completing their courses hence they (the institutions) are always in touch with the students. The institutions also added that they liaise with companies, 'if they (companies) need our students they phone us hence we do follow ups'.

The issue of resource availability has remained critical for optimum operation of both institutions. It is in this light that principals were asked to comment on the state of their human and material resources. The general comment was that there are highly qualified human resources but at times the institutions do not get the material resources required to produce quality products. In contrast, one principal (at Lobengula) highlighted that there is a shortage of staff because the posts have been frozen. She further elaborated that in the past they used to have courses like flower arranging, building and cutting and designing but due to frozen posts they are unable to fill these vacancies. Machinery was said to be in a satisfactory state but other machinery is now outdated hence the need to buy new ones.

Skills training link with industry and local business enterprises have been critical in the enhancement of skills depending on whether trainees get attachment or full-time employment opportunities. It came out in the findings that after institutional training trainees go for industrial attachment so that they get exposure of what happens there (in the industry) and what is expected of them. It was also highlighted that after completing their training all students go for attachments. One revelation was that most of the students are employed while on attachment. Companies always phone the institution(s) in need of the graduates.

Instructors also commented on the nature of vocational skills training. They possess qualifications that range from National Certificate, BSc Degrees, skilled class one metal fabrication experts, National Diploma and Advanced level. The years of experience for tutors ranged from one year to ten years across the two institutions. One lecturer in electronics revealed that during the period 2008 to 2012 more youth were keen train in various skills for them to be entrepreneurs. In carpentry and joinery one lecturer revealed that this course has been a male dominated trade with no female having enrolled for the period under study. On the overall, enrolment in this course was said to have been satisfactory. Findings for 2008 to 2012 enrolment showed that most youths who showed interest in training were more of females as compared to males. In metal fabrication, since 2000 the uptake among the youth has been on the rise. Unfortunately, as lamented by one lecturer, the girl child seems to be reluctant to venture into this trade.

In terms of the outcome of training, one lecturer in metal fabrication revealed that the outcome of training has been tremendous. He said, “Most of our graduates are either self-employed or working for companies. A lot of youth are coming forward to register and over the years we have recorded few dropouts”. The exposition by the lecturer has served as a pointer that skills’ training has been effective.

Lecturers in hairdressing concurred that the training has benefited a lot of students as they have been empowered practically. However, most of them have failed to get employed locally, while some have been employed in South Africa. An estimated 30 per cent of the students have something as they are gainfully employed in salons while 70 per cent were said to be self-employed through their backyard salons due to lack of operational space and funding. The employment opportunities for the trained youths were echoed by the Minister of Youth Development, Indigenisation and Empowerment that as a result of skills development programmes, Zimbabwe managed to export its skilled young people to Southern African countries like South Africa, Zambia and Botswana and even to Europe and Asia over the past years. This goes to show how skilled and versatile the young people of Zimbabwe are (26).

Commenting on employment outcome of training and students' fate after training, the lecturers revealed that after training there is always a challenge of starting up. Lack of capital, lack of bank collateral and also very high rates where an attempt to rent is made, are some of the factors that have hindered youth progress in terms of entrepreneurship. The foregoing observation is consistent with the view that several initiatives undertaken to deal with the problem of youth unemployment suffer from lack of coordination at the national level, inadequate funding and a business environment that is not enabling, with high inflation and high interest rates (27). The market was also professed to be also friendly as potential clients prefer to buy well established companies. For example, the food industry has absorbed many of the trainees. The lives of the trainees have improved as realised through reduction of crime levels and drug abuse. Generally, the lecturers concurred that some graduates get employed by industry and local workshops and market stalls, while others are self-employed. Some graduates, for example, are employed at the restaurants in the city centre while others engaged in salons around the city. Others who completed carpentry and joinery work have served as contract assistant workers to artisans in the refurbishment of Anchor House one of the Zimbabwe Open University premises along Fort Street and 12th Avenue in Bulawayo.

In respect of the follow-up strategies on the graduates, lecturers highlighted that random visits have been made to assess trainees at their places of attachment, employment and background workshop strategies have been used. Lecturers cited challenge of resources in follow-up exercises. Follow-up has been commended as a motivation to the trainees who are highly motivated during this period as they witness the seriousness of the centres, the government and the industry.

A challenge of resources for skills training was noted by the lecturers also who concurred that the resources are too few. One lecturer noted that training resources are not seriously considered as

evidenced in the very meaningless budget received by the vocational training centres (VTCs). As a result, highly qualified personnel always leave the departments, for example, carpentry and joinery, to join other Ministries who have well-established structures. Another dimension was given by one lecturer who revealed that there is adequate human resources at their training centre but, "the big challenge is inadequate training resources [consumables] forcing trainees to buy their own training consumables. This has disadvantaged youths from poor families". In addition, lecturers cited lack of state-of-the-art machinery and the high cost of repairing and servicing as compromising the quality of graduate output. In the areas of hotel and catering, hairdressing and home decor, lecturers expressed that, in the interest of quality, the departments should have at least two trainers instead of one because one trainer cannot train twenty students meaningfully in a practical subject.

The age range of respondents was between 16 and 30 years for both males and females from the two institutions. Thirty (30) trainees and graduates responded to the questionnaires from Sizinda Vocational Training Centre constituting eleven (11) males (37 per cent) and 19 females (63 per cent). From Lobengula training centre, twenty-one respondents returned the questionnaires, eight of the questionnaires were returned blank by the hotel and catering trainees, constituting a response rate of five males (24 per cent) and sixteen females (76 per cent). The general trend from both institutions shows that females are dominating the uptake of courses.

Table 2: Levels of Education (Trainees)

	Primary (Grade 1-7)	**Secondary (F1-F4)**	**Upper Secondary (F5- F6)**	**University/ College**
Sizinda	1	27	2	-
Lobengula	1	20	-	-

(Own Survey, 2012) **F** refers to **Form** (level of education)

Information gathered about trainees and graduates showed that most of them attained at least an "O" Level education. This pattern shows that the school leavers' category has grown hence the need to make a provision for the training of the post 'O' Level graduates so as to curb youth delinquencies. Until recently, formal education had become the rationing tunnel through which all prospective job-seekers and or holders must pass (28). It is no doubt that many current efforts on the part of the vocational skills training centres are being directed towards an educational system and content that improves and equips Zimbabwean youths for living (29). The tragedy of the youth has further been shown in that the problem of the unemployed school leavers has reached unprecedented levels. It is therefore questionable whether the academic focus of the education

system is relevant for the needs of the current economy. These school leavers have no experience, and no adequate practical skills, yet their academic qualification has imbued them with high aspirations for white-collar jobs (30).

Most youths from both institutions revealed that their tuition fees are paid by their parents. Two students in carpentry and joinery were said to have been sponsored by the International Labour Organisation (ILO). During their training which lasted for six months, the graduates attended attachment as part of their skills training at Kelvin North industrial area. Among other notable benefits from attachment, the students revealed that they learnt how to handle customers, gained experience in their acquired skills, learnt about marketing of their products and management of business. The exposure that students got is significant in having shaped them in prospective entrepreneurship.

Graduates in hairdressing also received sponsorship from the ILO for a course duration of one year. About seven graduates interviewed went through the course that was being offered on a full-time basis. Just like their counterparts in carpentry and joinery, these graduates had their industrial attachment in appointed salons in the city centre that included among others, Mandla's and Fingers Hair Salon. Graduates commended the attachment they received for enabling them to gain more technical skills in hairdressing and more hairstyles required by the clients. They also saw it as a way of gaining more work training and experience.

Lobengula also had a number of students in the different programmes that were sponsored by the ILO. For example, in home decor, ten trainees were said to be sponsored by the ILO for their course duration of twelve (12) months. The trainees expressed great joy with their training and were aware that they will attend attachment as one of their course requirements. Two of the youths who trained in metal fabrication had attended their training at Kelvin West industries and they applauded the gaining of skills and experience. Two graduates in hair dressing had attended their attachment at the local salons in Lobengula suburb. ILO has provided as part of its sponsorship package to students, kits for start up. For example, in carpentry the organisation has provided graduates with equipment and material to cushion them against the constraining economic rigours of starting own business.

The role played by International Labour Organisation in complementing government effort in equipping youth with the necessary skills is commendable as a demonstration of a policy that entertains collaboration and coordination (31). Having been in the business of skills training for some time, ILO has collected; simplified and synthesised information relative to the youth training that can supplement the government's development efforts. These mutually supportive relationships

have been an asset in promoting and augmenting the government's efforts at youth skills training and the reduction of youth unemployment in the nation (32).

In order to gain insight into the relevance of the skills trained, trainees were asked to comment on how the course has developed them as individuals. One youth trainee in hotel and catering course shared that, 'this course can take me a long way in my life to get enough money and to help my parent'. The other reasons given were that catering helps graduates to maintain their health and enable them to make a living. This realisation is consistent with a sense of self-employment and enrichment that the youths are envisaged to gain from their training. Others professed having gained in terms of knowledge of different types of food and their names. Catering also equipped the youth with the importance of hygiene and skills in cooking and the importance of nutrients in people's bodies. One respondent in the hairdressing course highlighted that the training received has developed her 'to work without supervision'. The latter is characteristic of a socially responsible individual consistent with national development. In the same course one trainee said, 'it [hairdressing] made me realise that I'm talented, I never thought that I can plait hair in my life'. One preferred to share in her mother language Ndebele that, '*iHairdressingingincedangokunengingobasengikwanisaukubambaimalingamanyeamalanga*' (hairdressing has helped me a lot because I can now afford to make some income on some days). Trainees saw themselves as having developed in hairstyling, plaiting, perm application and relaxing of hair of which some had no such skills when they joined training.

Trainees in electronics course which last three months revealed that they can now fix electronic gadgets on their own with one saying, 'I get money when I repair electrical gadgets and I can now identify a fault in a gadget and fix it'. This commendation by the graduates shows the positive and developmental impact of the vocational skills training to the youth.

Trainees in home decor revealed that they now know how to use the sewing machine, they can now start their own business in dressmaking and designing and that they can now be employed in sewing on the basis of their training. Among the items learnt are how to design a kitchen curtain and bedroom suits, how to decorate rooms and wedding ceremonies, cushions, matching of colours (colour scheme), sewing for hotels and homes, soft furnishing, and toilet sets.

One graduate in carpentry and joinery saw the course as having been his good source of income. He also added that the course has developed him as an individual by improving his standard of living. Another graduate in the same course said the course enabled him to manage and to start own business through indigenisation and economic empowerment. The foregoing testimonies are

consistent with the premises of the human capital theory that education and skills training create improved citizens and help to upgrade the general standard of living in a society.

Trainees were drawn to comment on their employment opportunities and where they believe the course is taking them. The responses were varied as some saw the courses opening opportunities for them to get educated, get jobs and better their lives. Others saw it as empowering them to do their own things like opening their own business, thereby contributing to the increasing of employment. Despite all this, it is tragic to note that some graduates prefer employment to self-employment. Their orientation is to seek employment rather than create employment for themselves (33). One respondent in hotel and catering said, 'I will acquire a lot of skills and now I will start earning my money and start helping my parents on their needs'. Another contribution was that, 'to be honest it is taking me to another level of life because I'm now going to be somebody to look after my family and to partake in the food industry in developing Zimbabwe socially and economically'. One perceptive youth in catering course saw the state of the economy in Bulawayo as an inspiration for her to do the course citing that the food industry is fast becoming the biggest employer.

One youth graduate in carpentry and joinery expressed that his aim is to do Class One in carpentry so that he will be an artisan. One hairdresser trainee projected herself owning a salon, helping her siblings with schools fees and also helping those in need. A skill such as hairdressing was seen by most youths as being beneficial and good source of income in neighbouring countries like South Africa and Botswana. A youth graduate who completed his course in electronics decried that there are no employment opportunities but 'I see this course taking me to my own place where I will be doing my own repairs of electrical gadgets'. A female student in the home decor course at Lobengula Training Centre said about her employment opportunities, 'I am so equipped that finding a good capital or loan I can open my own shop and create employment for others and live a life without lack as I had a disadvantage academically I have a talent physically, using my hands'. This is consistent with the study carried out in Harare's suburbs of Mabvuku and Tafara that revealed that youths are in need of financial support to facilitate their entry into the informal sector (34).

In terms of some social and economic benefits some students revealed that once trained and certificated they will have something to present (certificates) when looking for employment. The general trend was for the trainees to see themselves becoming professionals in their skills of specialisation such as hairdressing and opening own business (salon). One carpentry and joinery graduate saw his course as having an economic benefit of changing the rate of unemployment. He also added that he would contribute to the nation by reducing the import of furniture goods from

outside the country. Another graduate in the same course saw a social benefit of him integrating and mingling with other youths, sharing ideas with others. On the economic front he saw himself as now being able to meet and finance his everyday basic needs and those of his colleagues. Unemployment reduction was seen as a critical socio-economic benefit in the community as some youths would be employed. Graduates in home decor revealed how they have benefited by way of choosing quality material, how to fix a machine and also how to treat customers.

Trainees and graduates were called upon to comment on the available resources for skills training at their centres. One trainee in hotel and catering summarised thus, 'resources at our institution (Sizinda) are few we have only one stove that we use to cook in a class of twenty five trainees so it interferes with timely carrying out of practical lessons. The other thing is that water is a challenge because you can't do anything without water in the catering industry'. As for other utensils such as pots, pans, plates, baking trays, they are sufficient but mixing bowls were said to be worn out. Other reasons cited revealed that there are no big industrial machines and there is shortage of material resources. In hairdressing shortage of dryers and rollers was noted. Even reference texts-books that trainees are to use for research are not available. In the case of home decor course at Lobengula, trainees highlighted that they have the following machines: hand machine, heavy duty machines, domestic machine and over-locking machine which are in good working condition. Tables for machines were said to be rather scarce. Trainees wish to have imbroidal machines to advance other sewing skills. Trainees in carpentry and joinery also lamented shortage of machinery which is compromising the training. The same candidates expressed satisfaction with the consumables they get at the training centre.

Responses from the youth showed that they have not allowed the college and university vetting system through "O" level and "A" level requirements to put a ceiling to their future. One female trainee in the hairdressing course praised the training programme as a good option that youth who have not had an opportunity to get to Polytechnics, Teachers' Colleges and Universities can ever do. She saw training as a substitute to social-ills like drug abuse, prostitution and theft. Particularly, she cited that young girls, of whom she is part, are the biggest victims. A career for the girl-child will enable her to have a better future as an empowered responsible woman, assisting her family, community and nation at large. Notably, barriers to employment can block young people in the passage from adolescence to adulthood, which involves setting up a household and forming a family. There is some connection between youth joblessness and serious social problems such as drug abuse, petty crime and single parent families. High levels of youth unemployment may, at an

aggregate level, lead to alienation from society and from democratic political processes, which may give rise to social unrest (35).

On a familiarisation tour at Lobengula training centre the researcher observed that some graduates from carpentry and metal fabrication were attending a Business Management Training course. Both the principal and the trainees applauded the introduction of Business Management Training course as a point of entry into entrepreneurship. They alluded to the use of acquired skills in making-up their budgets to their own businesses, drafting business proposals, keeping of inventory of equipment as a sure way of evaluating whether their individual backyard businesses are making a profit or lose.

CONCLUSION

Vocational education and training has emerged as one sure way of creating entrepreneurs in the light of an economic plunge and uncertainty like that of Zimbabwe between the periods 2008 to 2012. From the numbers of trainees noted in the various courses, the potential is there for more youths to be enrolled hence there is need for vigorous vocational skills awareness. Youths should see the courses as not only meant for those without requisite "O" levels but as means of equipping one for lifelong service and relevance in life. In making this a success, there is need for technical minded lecturers and administrators.

Trainee enrolment is not gender balanced across the courses. There seems to be a skewed approach towards viewing courses such as dressmaking and hairdressing as being female domains and others such as electronics, welding and carpentry as being male domains. There is need for serious reorientation in terms of involvement of both female and male trainees in any available programme.

The discussion showed that vocational skills' training has enabled the school leavers and youth who have been disadvantaged academically but are skilled in handwork to acquire a career. Training has eliminated a culture of laziness and redundancy among the youth which ends up driving them towards delinquent behaviour. In the interviews it was quite clear that the long-term relief of poverty and unemployment could only be effected through self-reliance training provided by the two training centres. The curricula in these centres are therefore designed to provide youth with an opportunity to earn a livelihood and to effect an immediate improvement in living conditions.

From the responses gotten from most youths, vocational training from the sampled centres has empowered them from being dependents to breadwinners in their families. Some youths have earned income that has allowed them to pay school fees for their siblings. Meanwhile, it is notable

that levels of poverty in the families with skilled youths have greatly been reduced. To most youth, it appears that vocational training has assisted them in fully if not partially attaining their dreams, that is, to be able to exchange one's skill for a respectable income. Some have been gainfully employed in big supermarkets like TM Hyper and OK, while others have been integrated into hotels like Rainbow and popular restaurants such as Dickies and Chef Jiff, among others. It would be essential to refer to a word of advice from one of the youth, 18 years of age, who shared that, 'as youths it is important to learn to use our hands. If you learn to plait hair, sewing, cooking and some other activities it is easy to raise money to do something than to become a thief, robber or commercial sex worker. For a better life you must work'. This sentiment permeated the greater responses by all the respondents, principals, lecturers, trainees and graduates alike.

The findings from the study have aptly shown that no nation can move forward when its young people are trapped in cycles of poverty, limited education or when they are constrained by socio-economic factors that hinder their progress. There is a clear recognition that the youth are a vulnerable group that need protection by government and other supporting agencies and their own communities. Youth are the potential strength of a nation; they constitute the pillar upon which a nation is built. They are full of energy, enthusiasm and dynamism. Their potentials have to be channelled to enable them to play a constructive role in the socio-economic development of the country.

RECOMMENDATIONS

As much as the training centres have managed to brave the economic crisis and instead turn it around to a time of equipping, the outcry about the general scarcity of resources and funding for the institutions is something that the government and the responsible Ministry of Youth Indigenisation and Empowerment should consider reviewing upwards. More partnership should be sought with industry and local business enterprises where these centres are situated so that business can plough back to the centres as part of their corporate social responsibility. In the same light, latest state-of-the-art machinery should be sourced for all the courses across the training centres. Resources permitting, graduates in the various courses should be given loans and start-up kits that they can use to start their small businesses.

Operational space for the graduates who have failed to secure full time employment in companies should be sought. In this light, the Ministry of Youth Empowerment and Indigenisation should work together with the local municipal authorities like the Bulawayo City Council (BCC) for possible allocation of space where entrepreneur shops could be built for the youth to practice their

skills rather than training the youth and leave them to roam the streets with their certificates and skills that could be put to good use.

The government and other stakeholders in education should consider building more Vocational Training Centres to cater for hordes of school leavers and those without 'O' levels at all but need skills training. The idea of sponsorship in skills training, as noted with ILO, is commendable although the allocations and number of beneficiaries should be increased to cover more trainees most of whom usually come from poverty stricken and poorly resourced families.

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National and Regional Approaches to Multilingualism in Africa

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ABSTRACT

The paper examines multilingualism in Africa in terms of tendencies and trends in language policy formulation and planning and implementation at national and regional level. It argues that regional policy efforts to develop coping mechanisms or survival strategies have generally been contested by national orientated strategies. One example of resistance for complex regional research networks would be the notable decline of the once vibrant *Le Centre International des Civisations Bantu*. It further argues that at national level, academic policy and practice in all social science spheres, including multilingualism has placed emphasis on teaching at the expense of research in the mistaken belief that research was an appendage of teaching and that the two components were not necessarily complementary. One example of a slanted national system would be South Africa where university departments for humanities disciplines such as African Languages generally lack corresponding specialized research centers and institutes. (147 words)

Key Words: multilingualism, trends, language, Africa.

INTRODUCTION

This section first and foremost identifies language families represented in Africa. Secondly, it describes the socio-linguistic situation obtaining on the continent. Thirdly, it discusses the contribution of language and culture to socio-economic development of the region through tourism and other industrial activities. Lastly, it deals with linguistic conflict in the broad context of human conflict. These introductory remarks are necessary for clear understanding of multilingualism in the world generally and Africa in particular.

Language Families Represented in Africa

Unlike relatively poor regions of the world, Africa is endowed with various different language families.

Figure 1The language families in Africa (Dingemanse)

These are Afro-Asiatic (e.g. Amharic; Arabic, Berber, Hausa-Fulani, Somali); Nilo-Saharan (e.g. Acholi, Dinka, Luo, Mangbetu, Maasai, Nubian, Sarar, Sango); Khoi-San (e.g. Hadza, Nama, Sandawe); Nigero-Congolese A (e.g. Ewe; Yoruba; Wolof); Nigero-Congolese B (e.g. Bemba; Fang; Lingala, Setswana, SiSwati, Shona, Swahili, Zulu-Xhosa); Austronesian (e.g. Malagasy); Indo-European (e.g. Afrikaans; English). (See Greenberg 1963; Gordon 2005)

Socio-Linguistic Situation in Africa

The vast majority of Africans live in 54 nation-states that constitute African Union membership. This means that African people depend on Arabic, English, French, and Portuguese (African languages if possible) to communicate during international gatherings (Article 25: Working Languages, Constitutive Act African Union 2000). Such exocentric language policies raise the question of African sovereignty, self-determination and self-rule for African peoples (Kasonde 2000).

At regional level as exemplified by Southern African Development Community (SADC), a similar pattern could be observed with the use of English, French and Portuguese(Other languages as the Council may determine) (Article 37: Language, The Treaty of the Southern African Development Community 2001).

Within national boundaries, the general trend remains the adoption of former colonial languages as official media of communication. Examples include English (e.g. Malawi, Zambia, Zimbabwe), French (Gabon, Congo Brazzaville, Senegal), Portuguese (Angola, Mozambique, Sao Tome and Principe) and Spanish (Equatorial Guinea). Despite pressure to conform, certain countries have

instituted legal and political reforms aimed at rehabilitating African languages. Shining examples include South Africa and Tanzania and also Zimbabwe under the new proposed Draft Constitution (2012). At individual level, many African people are polyglot. Monolingual Africans are extremely rare.

Contribution of Language and Culture to Socio-Economic Development in Africa

Tourism generally and cultural tourism in particular represents a sustainable source of government revenue in most African countries. It generates employment and wealth creation (5% of direct global GDP; 30% of world export of services; 235 million jobs worldwide; 980 million international tourists in 2011; 1.8 billion international tourists by 2030; USD1.03 billion transactions involving tourists) (see www.unwto.org). To the extent that language and culture are interconnected, it can be argued that cultural tourism depends on linguistic diversity or multilingualism.

The second contribution of language and culture to socio-economic development lies in value-addition in areas such as advertizing, broadcasting, press, printing and publication. Instead of simply utilizing one language, such as English, nations that embrace multilingual policies such as South Africa create new spaces for freedom and free enterprise. This is achieved through promotion of various service providers, including interpreters, translators and teachers. Lastly, industries in multilingual societies tend to customize by way of creating specialized products for special markets. The specialized markets include computer platforms, hard ware, software, key boards and manuals and brochures for different languages.

Linguistic Conflict in Africa

Like all endowment, multiplicity of languages often engenders human conflict. Linguistic dimensions of human conflict in Africa manifest themselves in numerous forms. The first and most vivid manifestation of linguistic conflict takes the form of secessionism (Tigrinya-speaking Eritrea seceded from Amharic-speaking Ethiopia; speakers of Nilo-Saharan languages of South Soudan seceded from Arabic-speaking Sudan). The second manifestation of linguistic conflict is ethno-regional nationalism (Igbo-speaking nationalists of Biafra attempted to secede from Nigeria; Swahili-speaking Katangese nationalists attempted to secede from Lingala-dominated Congo Kinshasa; Ndebele-speaking Matabele nationalists attempted to secede from Shona-dominated Zimbabwe; Lozi-speaking Barotse nationalists attempted to secede from Bemba-dominated Zambia; Kiunguja-speaking Zanzibar nationalists attempted to secede from other Swahili-dominated Tanganyika mainland).

Apart from armed confrontation, linguistically motivated human conflict can express itself in different forms of passive resistance, such as rampant corruption, nepotism, defiance or self-pity. In all these cases, linguistic diversity momentarily or temporarily shifts from asset to liability. In these extreme situations, it is tempting to pile the blame on top of multilingualism per se and yet counter examples abound. For instance, genocide in Burundi and Rwanda occurred within the linguistic context of mono-lingualism.

OBJECTIVES

The major objectives of this study are four-fold:

a) To provide a description of multilingualism in Africa;
b) To identify language policies that address multilingualism in Africa;
c) To compare national and regional policies that deal with multilingualism in Africa;
d) To make recommendations that address concerns of speakers of endangered, marginalized or neglected languages in Africa.

METHODOLOGY

This section is divided into three parts. The first part provides definitions of key concepts. The second part deals with available literature. The third and last part addresses data collection and data analysis.

Definition of key concepts

To deal with national and regional approaches to multilingualism in Africa in a balanced manner, it is imperative to define key concepts. These are multilingualism, nation and region. Multilingualism is generally understood in two ways, namely personal or community. A multilingual person is a polyglot individual that speaks a language or languages other than his or her first language. The first language can be a mother tongue but in some cases it is a different language. Multilingual or polyglot individuals are quite common in society due to globalization and improvements in transportation and telecommunication.

A multilingual community can be provincial or national as along as using two or more languages is widespread. The term diglossia refers to co-existence of a low variety with a high variety (Ferguson 1959; Fishman 1968; Fishman 1972). Haitian Creole (L) and Standard French (H) exhibit such a relationship. Bilingualism is a form of multilingualism. Bilingual policies and practices are found in various territorial entities, including Belgium (Dutch and French), Canada (French and English) and Luxemburg (French and German). A few African countries, including Botswana, Lesotho and

Swaziland have also adopted official bilingualism as national policy. The dawn of democracy in South Africa in the 1990s introduced official multilingualism in that country. The Afrikaans-English exclusive model of bilingualism was replaced by an inclusive model of multilingualism (Afrikaans, English, isiNdebele, isiXhosa, isiZulu, Sepedi, Sesotho, Setswana, siSwati, Tshivenda and Xitsonga). A total of sixteen official languages have also been proposed in the new Draft Constitution in Zimbabwe. These are Chewa, Chibarwe, English, Kalanga, Koisan, Nambya, Ndau, Ndebele, Shangani, Shona, Sign Language, Sotho, Tonga, Tswana, Venda and Xhosa. The Ugandan approach to multilingualism also deserves mention (see Nsibambi 1971; Mukama 2009; Nabirye and De Schryver 2011).

The term 'region' here refers to two types of groups of countries. The first type corresponds to the grouping of geographically contiguous countries, such as East Africa, Southern Africa and West Africa. The second type refers to continental groupings, such as Africa region. In the course of the discussion, it will become increasingly clear that even the few African languages that enjoy bilingual status within their national boundaries, such as Setswana or SiSwati have not been accommodated in regional frameworks. This situation is at variance with existing practices in Europe. Unlike the case among African regional groupings, in Europe the reality of multilingualism has been implemented at European Commission (see Robertson 2012).

Literature review

The existence of multilingualism in Africa has been acknowledged and recognized by numerous studies (Alexandre 1967; Bamgbose 2005; Bamgbose 1991; Batibo 2005; Kashoki 1990; Kashoki 1982; Kasonde 2000; Chanda 1996; Hachipola 1998; Heine 2000; Meeuwis 1998; Ngalasso 1986). Official multilingualism has also started to appear in critical academic writing (Alberts 2011; Nosilela 2010; Alberts, Botha and Kapp 2010). According to critical literature, bureaucracy and red tape have not made the inclusion of selected African languages into 'officialdom' or 'mainstream' an easy task. In other words, there is an enormous gap between language policy and practice or legislation and administration in countries of Sub Saharan Africa. The African élite is still regarding African languages as an appendage.

"How successful are the NLUs in their contribution towards the development of the official languages within the multilingual dispensation and do they have a future?" The same question was raised by Alberts (2011: 25). During the Apartheid era Department of Arts, Culture, Science and Technology (DACST) financed only two national dictionary units. These are, Afrikaans Dictionary and English Dictionary (see DACST 1996). Delegates that attended Roundtable discussion on the

position and developmental status of African languages organized by Department of Higher Education and Training also agreed that ”more funding” needed to be made available to support dictionary compilation efforts, albeit general or technical dictionaries (2010).

Data collection and analysis.

The paper is based on data collected through direct observation and library research spanning over thirty years. This includes undergraduate and graduate studies plus teaching and research in Africa, America, Asia and Europe. Although the paper is complete and thorough in its treatment of multilingualism in Africa, it is possible that certain pertinent perspectives and views have been excluded, omitted or overlooked. It is therefore the reader’s duty to point out any missing information using appropriate ways.

FINDINGS

The first major finding is that multilingualism in Africa largely remains confined to the national sphere. When multilingualism has made regional inroads, the scope of regional activities has been largely superficial and lacking in political vision and financial commitment.

National approaches to multilingualism in Africa

(a) *Overlapping policies*

Four policy approaches are discernible in relation to multilingualism in Africa. The first policy approach corresponds to total ignorance and neglect of local idioms (rare). The second policy approach is equivalent to problem identification without any elaborate solutions (common). The third policy approach is partial solutions (common). The last policy approach is comprehensive solutions (very rare). In my view, there is de facto overlapping between all these policies in the actual implementation. For instance, the fact that Arab states in North Africa recognize the need to promote Arabic in official transactions does not necessarily mean that they are committed to the protection of tiny minority languages, such as Berber. Similarly, the state in Ethiopia does not seem to have a road map for the promotion of Oromo at the expense of Amharic. In another rare case in Africa, French-speaking countries and their Portuguese-speaking counterparts tend to manifest attachment to French or Portuguese more than the English-speaking countries do. The African elite seem to have a vested interest in the former colonial languages more than their less affluent compatriots. Hence, access to radio and television is often derisory. In more forthcoming countries such as Tanzania, one is overwhelmed by the willingness of the Head of State to address a Christmas message to the nation using Kiswahili for almost three hours on end.

(b) *University teaching departments*

Universities mushroomed after independence in Africa. In fact, the mention of university degrees is almost taboo as it represents a glaring example of social disparities between the educated rich elite and poor illiterate or semi-literate masses. One of the striking things about the university curriculum in many African universities is lack of teaching departments offering African languages. The University of Zambia, for example, finds it normal to establish the Confucius Institute offering Chinese language and literature. At the same time, the University of Zambia can not establish its Department of African Languages and Literature along lines similar to the University of Botswana, University of Nairobi, University of Dar es Salaam, University of Lesotho, University of Malawi, etc. In the area of teaching African languages and literature in university departments, the South African university model is ahead of its contemporaries in Sub Saharan Africa.

(c) *University research centers and institutes*

The link between teaching and research is a recognized universal principle. This principle has been either neglected or sacrificed at the altar of expediency and opportunism in many African universities (see Robert Gabriel Mugabe 2012). That is true particularly in the area of African Studies generally and African languages and literature in particular. The African Languages Research Institute (ALRI) at the University of Zimbabwe and Institute of Kiswahili Research (IKR) at the University of Dare es Salaam as well as the Centre des Etudes LinguistiquesThéoriques et Appliquées (CELTA) at the Université de Lubumbashi are extremely rare and exceptional publically funded research centers on the continent. The central argument of this paper is that has got to change (see Chabata 2008; Masuku and Ndhlovu 2007).

Regional approaches to multilingualism in Africa

The only achievement of African countries in the area of regionally based public institutional mechanisms for the promotion of Africa languages has been the establishment of Centre International des Civilisations Bantoues (CICIBA) (English Translation: International Center for Bantu Civilizations). Established at the initiative of Gabonese president Omar Bongo on January 8, 1983, CICIBCA is the world's primary organization dedicated to the study of the Bantu peoples. CICIBA's member nations include Angola, Cameroon, Central African Republic, Comoros, Republic of the Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Rwanda, São Tomé and Príncipe, and Zambia (http://en.wikipedia.org/. Access Date Friday, November 23, 2012). The initiative has been successful albeit with formidable national resistances. A critical view of CICIBA would need further redefinition linkages and networking. This could take the form of

budgetary and programming collaboration arrangements with regional bodies, including COMESA, ECOWAS, EAC and AU. The former OAU made certain tangible strides in the same direction under KayomboMateno.

CONCLUSION

The papers looked at national and regional approaches to multilingualism in Africa. At national level policies that seek to address multilingualism generally placed more emphasis on former colonial languages from Europe at the expense of indigenous African languages. In countries such as Uganda, South Africa and future Zimbabwe, the policy framework founded on multilingualism and the general principle of equality of languages need to be implemented. In particular the link between university teaching departments and university research institutes and centers also and to be established (e.g. University of Botswana) or strengthened (University of Zimbabwe). The paper observed that the worst case scenario was that of universities in Africa that lacked both teaching departments and research institutes or research centers for the study of African languages and literatures (e.g. University of Zambia). In terms of regional approaches to multilingualism, the paper observed that CICIBA was an isolated case and that the project was sustainable because it was feasible and viable.

RECOMMENDATIONS

The paper proposed the following policy recommendations.

(a) Dotting each national university with a teaching department for the study of African languages and literatures, using the University of Botswana as a model;
(b) Dotting each national university with a research institute or center for the study of African languages and literatures, using University of Zimbabwe African Languages Research Institute (ALRI) as model;
(c) Dotting each region with a regional research institute or center for the study of African languages and literature, using CICIBA of Gabon (ALRI) as model;
(d) Selling the idea of regional research institutes or centers for the study of African languages and literature to regional development bodies, including AU, COMESA, EAC, ECOWAS, SADC, etc;
(e) Doting the continent with a continental research institute, center or network for the study of African languages and literature, notably AU.

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LIQUIDITY DERIVATIVES AS SOLUTION TO ZIMBABWEAN ECONOMICLIQUIDITY PROBLEMS

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ABSTRACT

The Zimbabwean financial institutions and companies are faced with serious liquidity problems to meet their financial obligations since the inception of multi-currency system. The aim of this paper is to identify the source of current liquidity crisis and probable benefits of liquidity derivatives to ease economic liquidity problems. The Zimbabwe Stock Exchange listed OK Zimbabwe daily share price data from 19 February 2009 to 31 October 2012 was used. It has been found out that the market is the source of the current liquidity crisis. Therefore, it is strongly recommended that the ZSE should introduce the derivatives market which will ease the liquidity problems by attracting foreign investors, strengthening the monetary policy and security to would-be investors. Liquidity derivatives promote the optimization of commercial banks' capital structure and improve profit making abilities.

Keywords: Liquidity derivatives, price velocity, price acceleration.

INTRODUCTION

Financial disasters (such as the collapse of Trust Bank Corporation Limited, Barbican Bank Limited, CFX Bank Limited, CFX Merchant Bank, Intermarket Banking Corporation Limited, Intermarket Building Society, Intermarket Discount House, Royal Bank of Zimbabwe Limited, and Time Bank Zimbabwe Limited, and the subsequent establishment of the Zimbabwe Allied Banking Group (ZABG)) in the financial and banking sector in Zimbabwe in 2003 has been the major reason for having appropriate risk management techniques in place (16). After the introduction of multi-currency system, lack of liquidity led to Interfin Bank Limited to close its doors. Manufacturing companies are not spared and a number have closed their doors, downsize or relocated to Harare. The small banks and manufacturing companies failed to access funds to finance their operations, and service debts and loans. Thus a number of secular forces have led to liquidity risk management more important than ever before. One main role of the financial intermediaries is to provide liquidity. Liquidity and liquidity risk affects asset prices. Liquidity itself is not observable and

therefore, has to be proxied by different liquidity measures. There are different domains that can be used to define liquidity. In terms of security assets, liquidity refers to ease with which it can be cashed back or traded, even in large amounts, on a secondary market**.** Using market as a domain, liquidity can be referred to as market's ability to match supply and demand at low cost and its ability to absorb large trades without significant price impact.Finally, in terms of financial intermediaries, liquidity refers to institutions' ability to fund increases in assets and meet obligations as they come due, without incurring high losses (8).

The subject of liquidity has been well researched by different authors focusing on different aspects. Recently, (19) discussed the relationship between liquidity risks with other risks. Liquidity determinants in Zimbabwean banking industry were researched by (6). (5) looked at liquidity in banks. (18) researched on the determinants of financial system liquidity in Nigeria. (2) explained liquidity determinants in Saudi Arabia. The value of liquidity was incorporated in asset pricing model by (12). (14) discussed on liquidity risk and option pricing theory.(4) explained liquidity derivatives that can be used in managing hedge funds and described five instruments. Liquidity options were described by (11).

The paper is organized as follows section 2 explains the aims and objectives of the research. The section 3, discusses the liquidity derivatives in general. In this section we give a brief explanation on how they can be structured and priced. Section 4 looks at the data used in determining the source of liquidity crisis. Results are presented in section 4. Finally, section 6 concludes the research with recommendations.

The Zimbabwe's liquidity crisis requires an urgent solution and the aim of the paper is to determine whether the market itself is the source of liquidity crisis, and investigating the importance of liquidity derivatives. The Zimbabwe Stock Exchange (herein after ZSE) lacks innovation as compared to other African stock exchanges. The Johannesburg Stock Exchange (herein after JSE) is the most vibrant African stock exchange. The JSE offers derivatives instruments such as options, futures, swaps and swaptions to its large clientele base. JSE attracts foreign investors compared to ZSE. The Lagos Stock Exchange of Nigeria and Nairobi Stock Exchange are far ahead of ZSE in terms performance and liquidity (1).

LIQUIDITY DERIVATIVES

According to (7, 17), derivatives are a requirement to strengthen the financial market. Zimbabwe is in the time period of recovery and continuous growth, objectively requiring the deepening development of the financial market. The present situations of the Zimbabwe's financial market can be rescued by improving its effect of functions. ZSE lacks scientific pricing mechanism which can

improve market efficient. The financial market is not performing well among the following functions; gathering, distributing, adjusting and reflecting due to lack of scientific pricing mechanism. ZSE lacks the risk distributing function, which needs risk-shifting mechanism innately owned by the derivative instruments. Therefore, derivatives instruments are risk-shifting devices and can be generally defined as a private contract whose value derives from some underlying asset price, reference rate or index. The players of derivatives can be grouped into the three classes; hedgers for risk management purposes, speculators, and arbitrageurs.

Financial institutions can use derivatives to mitigate liquidity risk.

Derivatives are broadly categorized as lock or option products. Lock products obligate the contractual parties to the terms over the life of the contract and include; swaps, futures, and forwards. On the other hand, option products provide the buyer the right, but not the obligation to enter the contract under the terms specified and include; interest rate caps, liquidity options and withdrawal options. Therefore, liquidity derivatives are liquidity risk shifting devices and the instruments include; withdrawal options, liquidity options, liquidity swaptions, total return swaps among others.

The production of liquidity services is regarded as the key function of the stock exchange and thus greater liquidity can translate into lower cost of capital for the companies concerned. Therefore, purchasing liquidity derivatives is driven by the quest for higher liquidity. Liquidity derivatives' purpose is to capture, in the form of price changes, some underlying price changes or events. Derivatives serve as insurance against unwanted price movements and reduce the volatility of companies' cashflows, which in turn results in more reliable forecasting, lower capital requirements and higher capital productivity (3).

Liquidity Options

The first liquidity derivative is the liquidity option. The liquidity option, according to (4), is an option when the investor can withdraw his investment in a publicly traded asset at the market price if the liquidity of the asset is low. In this case, if the barrier is reached the option knocks-in, and the investor has the right to sell the asset to the option seller at the market price. In other words, the investor has the right to sell the asset to option seller at the market price if the barrier has been reached. Thus liquidity option can be referred to as knock-in barriers, and will be exercised as rates fall below the stated rate.

According to (11), pointed out that investors should consider purchasing liquidity options to meet unscheduled capital calls. Liquidity options pays off when liquidity is needed and obviates the need to hold cash when expected returns are high. However, the purchase of liquidity options depend on

yield on cash, opportunity cost of foregoing exposure to alternative risky investments, price of the liquidity option and investors' perception on the likelihood of capital call. To structure the liquidity option, we first need to identify the reference process that will provide a reliable signal for the demand for liquidity. The reference process must be observable and thus the option price depends on the volatility δ of an observable reference process, time to expiry T and the length τ of the liquidity interval. According to (10) and (11), liquidity options are cliquets or ratchet of the first-passage options, resetting at the start of every liquidity interval. Thus under the risk-neutral measure $\mu = r$, the price of the first-passage option is given by the following equation [1] below;

$$\Pi(\tau,\delta,B,S_0) = B\left(N\left(\frac{\ln\left(\frac{B}{S_0}\right) + \frac{\delta^2\tau}{2}}{\delta\sqrt{\tau}} \right) + \frac{S_0}{B} N\left(\frac{\ln\left(\frac{B}{S_0}\right) - \frac{\delta^2\tau}{2}}{\delta\sqrt{\tau}} \right) \right) \quad [1]$$

which can be written as equation [2] below, where $K = Be^{-rT}$ is the payoff of the option and K is the strike price, r is the interest rate, T is expiry date and S_0 is the initial stock price.

$$\Pi(\tau,\delta,B,S_0) = e^{-r\tau}\left(KN(-d_2) + e^{r\tau}S_0 N(-d_1)\right) \quad [2]$$

And $$d_1 = \frac{\ln\left(\frac{B}{S_0}\right) - \frac{\delta^2\tau}{2}}{\delta\sqrt{\tau}} = \frac{\ln\left(\frac{S_0}{K}\right) + r\tau + \frac{\delta^2\tau}{2}}{\delta\sqrt{\tau}} \quad [2']$$

$$d_2 = \frac{\ln\left(\frac{B}{S_0}\right) + \frac{\delta^2\tau}{2}}{\delta\sqrt{\tau}} = \frac{\ln\left(\frac{S_0}{K}\right) + r\tau - \frac{\delta^2\tau}{2}}{\delta\sqrt{\tau}} = d_1 - \delta\sqrt{\tau} \quad [2'']$$

The $N(.)$ is the cumulative normal distribution which can be obtained from the statistical tables.

Withdrawal Options

The second liquidity derivative is the withdrawal option. According to(4), defined withdrawal option as the right to transfer illiquid investment to the option seller at the market price. Withdrawal option allows the investor to withdraw its locked-up investment at the market price. The investor can be prompted to withdraw his investment if liquidity needs arises. It should be noted that the withdrawal option should be exercised anytime the option is at-the-money or in-the-money, and can

be priced as an American-style option. The withdrawal option gains its value because it allows the buyer to redeem an inferior investment. Therefore, this option is not used to protect against a value decline, but only against illiquidity (4). It can be priced as an American-style call option using the Black-Scholes formula as;

$$\Pi(\tau, \delta, S_0) = Max \left[0, (r_{fcd} - r_m)\right] \qquad [3]$$

where r_{fcd} and r_m are flexible certificate of deposit rate and market rate, respectively.

Total Return Swaps

The total return swap can be used as a liquidity derivative. According to (4) and (13), total return swap involves swapping an obligation to pay interest based on a specified fixed or floating interest rate in return for an obligation representing the total return on a specified reference financial asset. Total return swaps involves two parties swapping the total returns that is, interest plus capital gains or minus capital losses of two related assets. In a standard interest rate swap, one party pays a fixed amount while the other counterparty's payments are explicitly linked to a short-term interest rate.

Total Return Swaption

The return swap can be modified to become a return swaption. In other words, return swaption is an option to enter into a return swap. A swaption reserves the right for its holder to purchase a swap at a prescribed time and interest rate in the future and can be a payer or receiver swaption. The swaptions are used to mitigate the effects of unfavorable interest rate fluctuations at a future date that may lead to liquidity crisis. So by hedging interest rate risk, the company will be hedging against liquidity risk (3, 9, and 15)

METHODOLOGY

To determine the source of liquidity crisis, we analysed price velocity and price acceleration. Through analyzing the speed at which the price moves up or down, give an insight to ascertain whether the ZSE is the source of liquidity crisis. The ZSE listed OK Zimbabwe daily share price was used. The data used was from 19 February 2009 to 31 October 2012. The OK Zimbabwe daily share price data was accessed through OK Zimbabwe website. The retail outlet was chosen basing on share performance and availability of data. The equation [4] below is the formula for calculating price velocity and can be defined as the speed at which price move over time measured in x cents per day (xc / day)

$$P_v(t) = \frac{P(t) - P(t-i)}{i} \qquad [4]$$

Where $P_v(t)$ is the price velocity and $P(t)$ is the share price at time t. Then the price acceleration can be computed by equation [5] below and refers to the speed at which price velocity moves over time measured in x cents per day per day (xc/day^{-2})

$$P_a(t) = \frac{P_v(t) - P_v(t-i)}{i} \qquad [5]$$

Where $P_a(t)$ is the price acceleration at time t. The Minitab 10.2 software was used to analyse the data

RESULTS

Referring to figure 1, the daily share price is increasing fast in the first half year of 2009, when the country had introduced multi-currency system. Then the second half year of 2009, the share price was constant and this was due less liquid in the market. From June 2012, the share price increased constantly but at a slower pace. In the period year 2010, and 2011 to 2012, price movements are static. Trading in the market is not benefiting either the seller or the buyer. Thus price movement discourages speculators to fully participate in the market.

We can further analyse the share price velocity and price acceleration. Referring to figure 2, the price acceleration is concentrated in the region between $-2c/day$ to $2c/day$. However, price acceleration is oscillating between $-0.5c/day^{-2}$ and $0.5c/day^{-2}$, indicating small change in prices. Thus, we can infer that there is minimal trading activity taking place in the market. The price velocity and price acceleration are static, not indicating significant price movements in any direction.

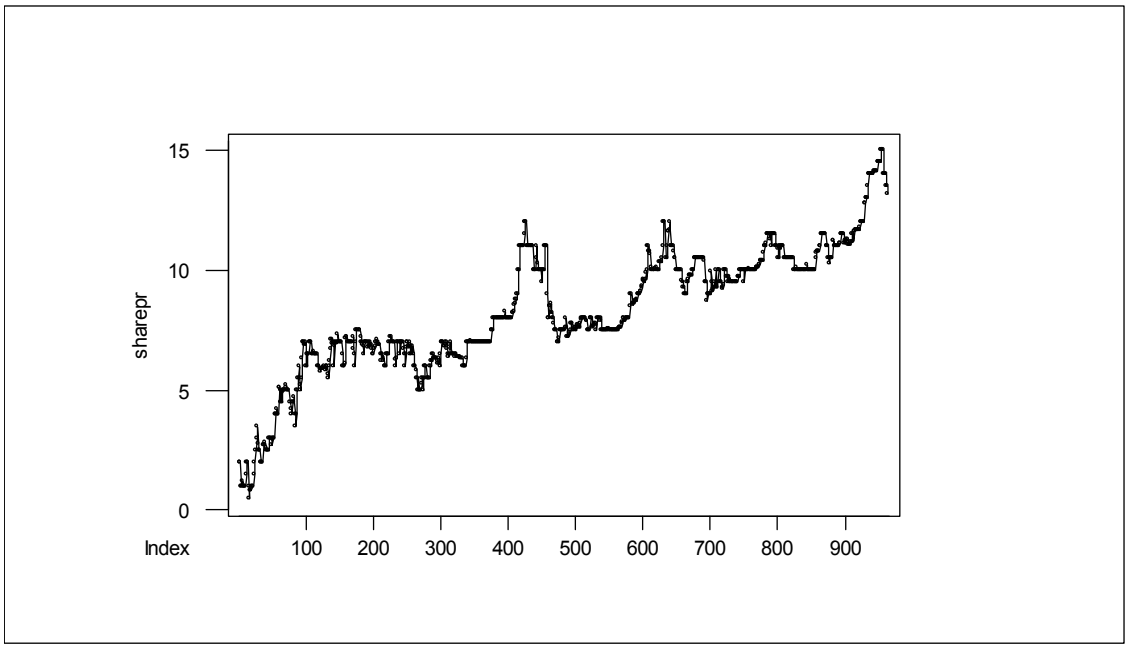

Figure 1: Daily Share Price

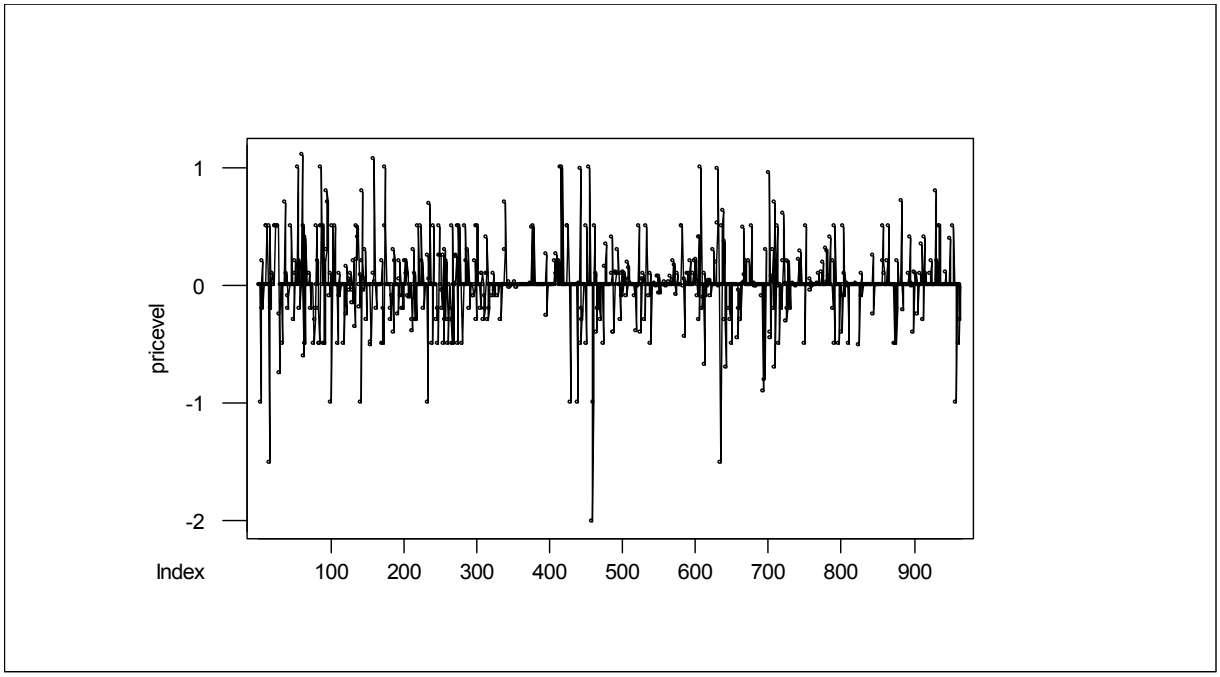

Figure 2: Daily Price Velocity

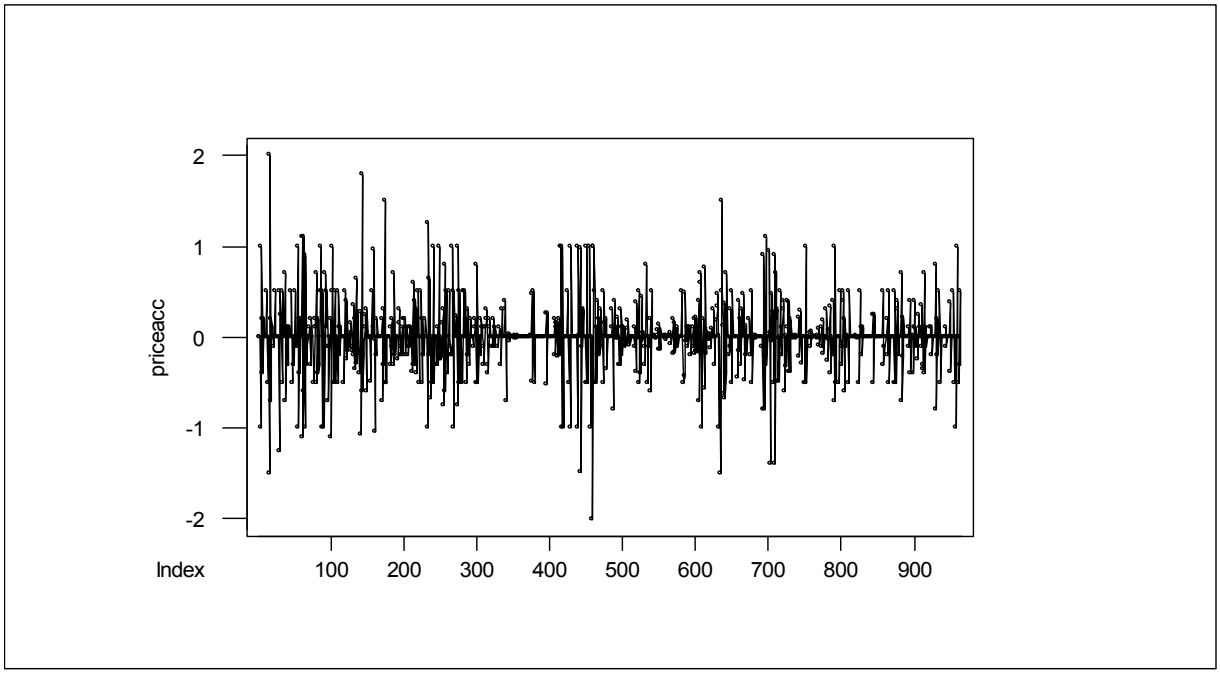

Figure 3: Daily Price Acceleration

DISCUSSIONS

In Zimbabwe, the stock market trading activities are still at infancy stage. Traders are optimistic and ought not to be much involved in ZSE activities. The investors are being locked-in to their investments and market-makers are being exposed to increased risks. Thus the Zimbabwean economic sphere of liquidity problems are mainly caused by less active market participants as signified by price acceleration in figure 3. In other words, high price acceleration either to the negative or positive side implies that the market is active and trading is taking place. Notable price movements in any direction can be catalysed by introducing derivatives in the market. Speculators will push the price up or down permitting active trading on the stock market. The foreign investors are taking the back seat and are reluctant to invest on ZSE due to lack of hedging instruments and capital liquidity.

Zimbabwean liquidity can be encouraged by opening up competition in trading venues. The liquidity provision is more robust when market participants have a choice between trading models. It is noted that speculators and market-makers are the key contributors to the liquidity of ZSE market by putting up their capital in seeking to arbitrage differences in risk or time preferences. The liquidity derivatives allow market participants and the Reserve Bank of Zimbabwe (herein after RBZ) to extract forward looking, as opposed to historical information, especially in crafting the monetary policy. So all in all, we can infer that the ZSE performance is the source of liquidity crisis

and there is urgent need for financial innovation. This is evidenced by non-active of the money market.

Establishing the derivatives market provides a number of economic benefits. Being speculative in nature, it provides the investor with a perception of the market not only in terms of current prices, but also in terms of the future. Derivatives markets transfer risks from those who have no appetite for them to those who do. Thus the ZSE market will enjoy higher trading volumes from more players as a result of risk mitigation. In a nut shell, the derivatives market will attract creative, educated, vibrant and intelligent investors who make optimal use of the opportunities offered and transfer their enthusiasm to new entrants as well. This perpetuates the entrepreneurial spirit within the economy, and not only creates better and new products, but also has a positive effect on the job market.

CONCLUSIONS

Introducing the derivative market is very crucial to Zimbabwe's economic growth and liquidity. The successful countries in the region such as South Africa, Nigeria and Kenya have proved the importance and necessity of the derivative market, which probably accelerate their economic growth. The benefits of liquidity derivatives are threefold; liquidity risk management, price discovery and enhancement of liquidity. In establishing the derivative market, it will strengthen the country's monetary policies effect by providing the RBZ with ample and effective information through its scientific pricing mechanism, enough instruments and rational expectations about market. Thus the market can effectively improve the accuracy of monetary policies.

The derivative market itself will help in efficiently and effectively absorb foreign capital that the country desperately need. The market will protect foreign investors who are currently reluctant to invest in Zimbabwe's market due to lack of safety and capital liquidity. Thus the abundance of ZSE instruments will provide foreign investors with more choice of ways of entering and withdrawal to improve the liquidity profit. Liquidity derivatives and other derivatives in general, promote the optimization of commercial banks' capital structure and improve commercial bank's profit making ability thereby improving liquidity and economic development. In a nutshell, markets with derivatives have more liquidity and thus lower transaction costs compared to markets without derivatives. So the derivatives market can be extremely beneficial for both individuals and the overall economy of a country.

Therefore, it is strongly recommended that the ZSE should introduce new financial products through establishment of a derivatives market. Establishing a derivatives market is feasible because the country has already a functioning underlying market. Here, entrepreneurial players are energized to create new businesses, products and concomitant employment opportunities from the profits they make from the derivatives market. A task team should be established to oversee the operation of the market. In addition, the task force needs to educate market participants and stakeholders on operation of the market, for it to be success.

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The Relationship between Ownership Structure and Firm Performance: Case of Zimbabwe 2009-2011

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ABSTRACT

The study investigates whether foreign owned firms perform significantly better than domestically owned Zimbabwean corporations quoted on the Zimbabwean Stock Exchange (ZSE). In the study, linear regression model was employed to examine if there are significant differences on operating profit margin (OPM), Return on Assets (ROA) and Return on Equity (ROE) between foreign owned firms and domestic listed firms. The results reveal that the firms with foreign ownership operating in Zimbabwe perform better than domestic owned ones in respect to ROA, ROE and OPM. The evidence supports the hypothesis that foreign ownership participation increases the performance of firms. The research is applied to a three year period 2009 -2011. The findings may guide the foreign investors who intend to participate on the Zimbabwean market.

Keywords: Ownership Structure and Firm Performance.

INTRODUCTION

Foreign ownership's influence on firm performance has been a topical issue in academia with many researchers arguing that foreign owned firms perform better than domestic firms. In this context this paper examines the relationship between firm performance and foreign ownership.

Several international surveys have shown that the single largest component of net capital inflows to emerging markets is foreign direct investment (FDI) Deutsche Bundes bank (2003). These are long term investments from investors, multinational corporations (MNCs) and other bodies from outside the country. The aim of this research was to determine the impact that FDI has on firm performance.

Generally, FDI can be defined as a form of investment that sees the investor obtaining a lasting interest by a resident entity of one economy (direct investor) in an enterprise that is resident in another economy (the direct investment enterprise). The lasting interest implies the existence of a long-term relationship between the direct investor and the direct investment enterprise and a significant degree of influence on the management of the enterprise. Direct investment involves

both the initial transaction between the two entities and all subsequent capital transactions between them and among affiliated enterprises; both incorporated and unincorporated (IMF 1993; Organization for Economic Cooperation and Development (OECD) 1996).

An important benefit is the increased availability of capital from overseas which is important, as domestic capital markets in emerging markets are rarely substantial enough to provide adequate financing for the corporate sector. Further benefits include additional jobs which can provide workers with higher levels of training and greater wages, advanced technology which can increase local productivity, lower production costs and advanced management techniques Cohen (2007). With all these benefits it is important for the governments of emerging markets and policy makers to be aware of the factors/determinants that can attract FDI.

Foreign direct investment (FDI) in Zimbabwe averaged 18% of Gross Domestic Product (GDP) in the 1980s and 20% in the 1990s, was a mere 1.1% between 2000 to 2009 (Zimbabwe National Budgets).Zimbabwe's capital account inflows, thus, remain a sad story, with 2011 foreign direct investment levels at US$125 million (Zimbabwe National Budgets). The central objective of this study then is to determine whether ownership structure has a relationship with firm performance.

LITERATURE REVIEW

Foreign investment and firm performance in Zimbabwe

From independence in 1980 until 1991, the government was very defensive toward foreign investment, subjecting each proposal to careful scrutiny and requiring foreign investors to get permission from the Foreign Investment Centre for the development of any new enterprise in Zimbabwe. Enterprises could be 100% foreign owned, especially in priority areas, but there was (and is) in effect a strong preference for joint ventures with at least 51% local participation.

In 1991 there was some revision of the regulations but the emphasis on indigenization remained at least as strong as the emphasis on the need to attract foreign investment. There is a long list of reserved sectors, but priority areas are offered a schedule of tax and tariff exemptions and incentives. Incentives are aimed at encouraging capital investments, the transfer of technology, the utilization of local raw materials, the development of rural areas, the use of labour-intensive methods, and the hiring of local personnel. Industries geared toward exporting that meet Export Processing Zones (E.P.Z) requirements receive tax holidays and customs free trade. In 1992, as part of a structural reform program under the (International Monetary Fund) IMF's Enhanced Structural Adjustment Facility (ESAF), the Zimbabwe Investment Centre (ZIC) now the Zimbabwe Investment Authority (ZIA) was established as a one-stop shop for investment processing. In 1995,

disbursements under the ESAF program were suspended for failure to meet IMF targets, and in 1996, the government substituted a second plan, the Zimbabwe Program for Economic and Social Transformation, (ZIMPREST), whose operations investors have found much less satisfactory. By the late 1990s, political turbulence and the government's defiance of the IMF had greatly increased investor risk, and brought foreign direct investment flows to a standstill.

According to the report compiled by the United Nations (UN) Conference on Trade and Development, FDI in Zimbabwe totaled US$60 million in 2009, up from US$52 million recorded in 2008 . The increase in investment level has, however, not translated in the overall growth of the country's major sectors, whose economic projections were revised by Finance Minister TendaiBiti in the 2012 National Budget. The Ministry of Finance projected mining to register a 31% growth from the previous 40% while manufacturing growth forecast is now down at 4,5% from 10% while tourism is expected to grow by 3,5% instead of 10%.Construction is expected to grow by 1,5%, transport and communication by 3% and public administration 2%, while electricity, gas and water production is forecast to shrink by 1,8 %. Agricultural growth, however, has been upgraded to 18%, 8% from the previous 10% due to a rebound in tobacco production which surpassed the 100 million kilograms in 2011, Tobacco Marketing Board (2011).

Comparative advantages of Multi-National Enterprise (MNE) affiliates and strategic patterns

The most frequently-mentioned explanation argues for a superior performance of foreign owned firms in almost all fields and can be labeled the "specific advantage hypothesis" (Bellak 2004: 486). The theory dates back to seminal work by Dunning (1988) and Caves (1974 and 1996: 162-180) and was developed in an attempt to explain the origin of internalized international firm activities through foreign direct investment (FDI). According to Dunning's prominent OLI-paradigm, a firm-specific ownership advantage is a necessary precondition for domestic firms to become a MNE. This advantage can either be tangible or intangible (like advanced technology or organizational superiority) and is available to affiliates within the MNE network at low marginal costs due to its public good character. Thus, foreign-owned firms, which participate in a multinational network, are endowed with a genuine comparative advantage over their domestic counterparts which are not part of an MNE. However, there is another possibility for MNEs to attain a firm-specific advantage, the neglect of which constitutes the primary criticism of Dunning's paradigm (e.g., Casson 1987: 33). Comparative advantages can emerge after a business becomes multinational due to the fact of being multinational or being geographically diversified, respectively. For instance, benefits can result from better access to markets and resources in a material and immaterial sense, as well as from overall flexibility to shift activities or profits across

borders. Nevertheless, in the context of this work, this theory offers a theoretical explanation for why foreign MNE subsidiaries could exhibit performance advantages over domestically oriented firms, whether they result from prior advantages of MNEs or network effects.

Since an MNE consists of various sub-entities, each entity can play a different role within the network and follow individual strategic patterns. Assuming that affiliates aim to source technology or knowledge or operate as an export platform, specific advantages of the parent instance, a more efficient production technique - must not inevitably be transferred to the affiliate. The same applies for acquisitions of competitors for reasons of market power or the acquisition of poor performing with the purpose of enhancing firm value in the future. In general sourcing strategies of business firms have become more complex than ever before, and so have the integration strategies of multinational corporations" Helpman (2006). It becomes apparent here that the comparative performance of MNE subsidiaries depends heavily on the type of activity they are involved in and that the unit of analysis can play a major role for theoretical assumptions as well as empirical results, whether it be headquarter or affiliate, enterprise or establishment.

From the above discussion, one can conclude that the presented considerations solely cover participants of multinational networks and ignore cases in which firms are foreign controlled but not part of a company network. Furthermore, the discussion only applies to comparison between foreign-owned firms and domestically-owned non-multinationals. Even if all units in a considered population were foreign-owned multinationals or domestically-owned non-multinationals, assumptions based on the idea of comparative advantage are not as clear cut as is often implied in the literature due to the heterogeneous roles and strategies of MNE affiliates.

Country-of-origin effects

Apart from the aforementioned explanation for a performance gap, a second, well represented line of argument has been described that refers to the owner's identity in terms of nationality. Contrary to the perception of multinationals as "footloose" or "stateless" that lost any imprint of their national origin in the convergence process of economic and cultural globalization, stands the vast consensus that the notion of the global corporation transcending national boundaries is, very largely, myth (Ferner 1997: 19). Following empirical evidence, various researchers assume that a MNE´s home country influences firm performance in the fields of human resource management and industrial relations, but also on productivity measures. Outcome differences in firm performance are traced back to variations in the institutional arrangement of the national business systems, such as labour market regulations (Whitley 1992), overall cultural differences that manifest themselves in the respective firm´s corporate governance structure (Hofstede 1992), and different factor

endowments. However, a sharp separation of these mechanisms from one another seems certainly unfeasible. Therefore, MNEs should be perceived as a "two-way vector of dynamic change within national business systems – both bringing to host countries their own nationally distinctive ways of doing things, and taking from the host environment lessons for adoption at home" (Ferner et al. 2001: 124).

One can emphasize that theoretical consideration assuming country-of-origin effects are likewise not suitable for implying a universal and intrinsic impact of foreign ownership across countries. This is because particular attributes of firms, traced back to the country of origin, do not vary among national borders in absolute terms and are therefore much more consistent than the characteristic of being foreign-controlled. Although such considerations are more conceivable in the context of MNE affiliates rather than with foreign-owned firms, the influence of something like a "national culture" or business culture on firm performance could be extended to the latter as well. However, the general direction of potential country-of origin effects is not obvious and should be varying.

Foreignness

One more major line of argument can be identified in the literature of international firm activity and appears to be the only one that bears the ability of explaining a causal effect of foreign ownership. It is thus astonishing that these considerations have, never been explicitly set out separately in the context of a comparative performance of foreign-controlled firms. The term "foreign-owned" does not primarily imply that the owner is of a special nationality, but that the owner is not of the nationality of the economy in consideration and therefore a stranger. In other words, the feature referred to in this case is first and foremost her or his foreignness, and not being of a specific nationality. Theoretical considerations generally point out the "liability of foreignness" (Daamen et al. 2007), which can be induced through extra costs required to overcome various obstacles, such as communication issues (spatial distance, different languages and intercultural mistrust) and transport Buckley (2000: 294), as well as the additional effort in monitoring work processes and searching for appropriate employees resulting from information deficits in foreign markets (Feliciano and Lipsey 2006: 75).

The additional costs of foreignness are already incorporated in the idea of specific comparative advantages and the corresponding assumption that the advantages outweigh the disadvantages (Buckley 2000: 300). However, foreignness may merit separation of this assumption to demonstrate that a foreign ownership variable can indeed capture more than just a residual of "status-specific parameters influencing a firm´s performance that cannot be specified otherwise" (Güntherand and Gebhardt 2005: 96) as it is supposed to be the fact at times in the literature. Certainly, a proper

method of measuring and isolating this effect is far from easy since learning effects over time may add a dynamic dimension.

Specific measures of performance

While the outlined arguments thus far apply to productivity measures in principle, which is surely the aspect of performance that has received the most attention although productivity can have a basic influence on other measures itself. Profitability reflects comparative advantages that are not inherently included in productivity. The two normally go hand in hand, since relative productivity advantages or disadvantages should mirror a direct impact on profitability in the same direction. However, this is not necessarily the case if accounting policy criteria are taken into consideration.

For example, MNEs could shift profits from high- to low-tax countries through the manipulation of transfer prices to reduce their tax burden. Indeed, beyond subjective evidence, Dischinger and Riedel (2008) provide empirical evidence for the bias of intangible assets within MNE affiliates towards low-tax affiliates, what can be assessed as a hint for profit-shifting activities as a facilitation of the latter. Thus, a potential dependence of measured profitability on the affiliates´ tax environment is revealed.

Wages paid by foreign-owned firms are often expected to be higher on average, compared to those of domestically-owned firms, resulting from distributing higher profits through bargaining (Girma et al. 2002: 94), prevention of job turnover (Sjöholm and Lipsey 2006: 203), or compensation for disadvantages on the labour market (Feliciano and Lipsey 2006: 75). Hence most considerations point to multi-nationality status rather than foreign ownership as the main causal factor. Unfortunately, this study remains highly descriptive regarding a wage gap, because data used neither allows controlling neither for different skill levels nor for actual hours of work what makes it impossible to draw any reliable conclusions on the paid price for the labour factor and the independent of its quality.

Moreover, it should not be astonishing if a non-ambiguous effect of foreign ownership cannot be identified in empirical research since already according to theoretical pre-considerations it is primarily multinationality (as a special case of network effects) that seems to affect performance. On the other hand, one should not rule out the possibility of a causal relationship between foreign ownership and performance.

EMPIRICAL LITERATURE REVIEW

Empirical results from developed economies

Research on firms with foreign ownership operating in developed countries, Goethals and Ooghe (1997) conducted a study to investigate the performance between 25 Belgian firms and 50 foreign companies, which are Belgian taken over by foreigners. They calculated twenty-eight financial ratios for both foreign and domestic firms and concluded that foreign takeovers have a positive impact on the performance of firms. Moreover, the firms with foreign ownership performed better than their domestically owned counterparts. Besides (Alan and Steve 2005) also looked at the short and long term performance of UK corporations acquired by foreigners for the period 1984-1995 and the study revealed that there is a significant positive returns on the firm performance.

Most importantly, multi-nationality has a significant impact on the performance of MNEs. This might be due to market imperfections providing a powerful motivation to MNEs to explore the multinational ownership advantages such as managerial skills and marketing ability. Lin et al. (2000) looked at the issue from different angle and examined intra-industry productivity spill over from FDI on manufacturing sector in UK. The findings indicate that FDI existence has a positive spill over on the productivity of UK owned firms. Piscitello and Rabbiosi (2005) extended the study to Italy to investigate the influence of inward FDI coming into existence through acquisitions. The empirical results consist of foreign acquisitions that occurred in Italy for the period 1997-1997. Their sample was based on 113 foreign acquisitions, 74 of them undertaken by European MNEs, 31 by US MNEs and 8 from other countries

Although, it is commonly agreed that foreign owned firms and MNEs have been performing better than their domestically owned counterparts, Kim and Levn (1990`) made contrasting revelations. Their research aimed at evaluating the performance of MNEs operating in the U.S. and their empirical sample for the study was based on the 54 largest foreign corporations operating in US in the period of 1980-1984. The corporations are grouped into the different industries. Nine of them are in mining, twenty-nine in manufacturing and sixteen in other industries. The results (Kim and Levin, 1990) indicate that foreign owned firms operating in the USA are less profitable than randomly selected domestically owned U.S corporations. Reasons for that might be US firms have a research and development (R&D) initiatives and more advertising than foreign owned firms.

Empirical results from developing and transitional economies

Studies of firms operating in developing and transition economies to test the effects of FDI on productivity performance of firms were carried out in three developing economies: Bulgaria, Romania and Poland (Konings, 2001). Bulgaria consists of 2 321 firms for the period of 1993-1997,

3 844 firms in Romania between 1994 and 1997 and 262 firms in Poland over the period of 1993-1997. The evidence shows that foreign corporations do not perform better than domestic ones, except in Poland. This might be due to taking time for foreign ownership impacts on performance. Moreover, there was no evidence of positive spill over of foreign investment to domestic firms. Khawar (2003) also finds no evidence of spill overs in Mexican manufacturing industry although the study revealed that foreign firms are more productive than domestic firms because of indication the presence of a strong foreign ownership on the productivity of individual firms. Aitken and Harrison (1999) find no evidence of spill-overs from foreign firms to domestic owned firms in Venezuela. They employed the data set of 43,010 observations covered from 1976 to 1989 that was gathered directly from Venezuela's National Statistical Bureau. They estimated log-linear production functions to investigate if foreign ownership is related to an increase in the productivity of plant and whether foreign equity participation has positive or negative spill-overs to domestic firms. The findings show no evidence supporting the presence of technology spill-overs to domestic firms from foreign firms.

METHODOLOGY

In order to estimate the link between ownership and performance, it is necessary to decide on the appropriate indicators. Profitability, which is widely viewed as the best measure for corporate performance (Kocěnda and Svejnar, 2002) is the major variable used in this study. However, labour productivity, proportion of sales exported, investment propensity and firm growth were applied to a lesser extent in the research.

Return on Equity

This ratio indicates how profitable a company is by comparing its net income to its average shareholders' equity. The return on equity ratio (ROE) measures how much the shareholders earned from their investment in the company. The higher the ratio percentage, the more efficient management is in utilizing its equity base and the better return is to investors. For example, if returns on equity happen to be 15 percent, this implies that for every dollar invested in equity there was 15 cents return.

$$\boldsymbol{ROE = \frac{Net\ Income}{Equity}\ X\ 100}$$

Operating Profit Margin

By subtracting selling, general and administrative (SG&A), or operating, expenses from a company's gross profit number, we get operating income. Management has much more control over

operating expenses than its cost of sales outlays. Thus, investors need to scrutinize the operating profit margin carefully. Positive and negative trends in this ratio are, for the most part, directly attributable to management decisions.

$$OPM = \frac{Operating\ Profit}{Total\ Sales}\ X\ 100$$

Return on assets

This ratio indicates how profitable a company is relative to its total assets. The return on assets (ROA) ratio illustrates how well management is employing the company's total assets to make a profit. The higher the return, the more efficient management is in utilizing its asset base. The ROA ratio is calculated by comparing net income to average total assets, and is expressed as a percentage.

$$ROA = \frac{Total\ Income}{Total\ Assets}\ X\ 100$$

Ratio shortcomings and solutions

However, there are potential problems with the usage of the above-mentioned ratios. ROE is subject to the most serious accounting distortions. The problem is that the positive ROE does not always suggest that a company is profitable. This is due to the fact that many Zimbabwean firms report negative equity in their balance sheets. If the corporation incurs losses during several accounting periods, accumulated losses appear in the equity section of balance sheets and may result in negative value of equity.

Therefore, positive values of ROE may occur as the ratio of two negative entries, loss to equity. It may turn out that the loss maker has a positive return on equity; therefore this measure has nothing to do with the actual firm performance. As to the remaining ratios, ROA and, OPM may also suffer from the accounting errors (both random and intended), missing values in financial reports that cause the bias in estimation. However, they can be mitigated by applying screening procedures, as many researchers do (e.g. Kocěnda and Svejnar, 2002). The magnitude of possible distortions in measuring ROA and OPM is therefore much smaller than in the case of ROE and these profitability ratios are considered to be appropriate performance measures. Thus, to reduce biased estimations caused by these ratios, this research will refer to several performance measures rather than to the single indicator in order to compensate for individual shortcomings.

The model

$$\boldsymbol{Firm\ Perfomance = \beta_1 Ownership + \beta_2 Leverage + \beta_3 Firm\ Size + \beta_4 Liquidity + \mu}$$

Where: - $\boldsymbol{\mu}$ is the error term.

Leverage

Leverage is measured as the ratio of total debt to assets. Higher leverage increases the risk of bankruptcy and is associated with firm dependency and bargaining power in the capital market, as Barbosa and Louri (2003) suggest. At the same time, leverage increases profit opportunities. The on-going debates on relationship between variable of interest refrain from making strong predictions on the ex-ante sign of effect.

Firm size

Firm size (measured by the logarithm of company's assets) is positively related to profitability in case the firms make use of the economies of scale and scope. The logic is that the large firms have all options of small firms, and, in addition, their scale allows investing in projects that are not available for small firms (e.g, Hall and Weiss, 1967). However, the management of large companies is associated with more bureaucracy and increasing monitoring costs. One possible explanation of the negative relationship between firm size and performance is the separation of ownership and control in modern corporations.

The conflict of interests between managers and owners arises when managerial utility maximization replaces profit maximization as the firm's objective function. This separation may increase with firm size; therefore large firms are more vulnerable to managerial discretion (Ammar et al., 2003). As empirical studies provide varying results for firm size-performance relationship, but do not make a strong prediction on the sign of the relationship.

Liquidity

Liquidity is a measure of asset management efficiency and reflects the speed of assets conversion in order to respond to profit opportunities (Barbosa and Louri, 2003). Liquidity can be measured by several ratios, such as quick liquidity ratio (cash-to-current liabilities ratio) or current ratio (current assets-to current liabilities ratio), and this study employs the current ratio when measuring liquidity. Efficient liquidity management balances the risks of inability to pay out short-term obligations with the avoidance of excessive holdings of liquid assets which do not bring the return until they are

invested. Liquidity-profitability trade-off is discussed in detail by Abuzar (2004) who finds significant negative relation between the firm's profitability and its liquidity level, as measured by current ratio.

Research findings

This research undertook an analysis of performance of firms with foreign ownership to test its effect on the firm's performance and examine whether there is any significant performance difference between firms with foreign ownership and domestically owned firms listed on the Zimbabwe stock exchange.

In this study the t-test statistic for FDI showed that FDI percentage which is the variable for foreign ownership is the second largest predictor of firm performance after firm size with a t-statistic of 9.764 that is ROA. The same can also be said for ROE in which FDI is the second largest contributor to firm performance in the model with a t coefficient of 3.519. FDI percentage has a negative t-statistic of -1.745 meaning that under the OPM model FDI percentage is a poor predictor of firm performance. Therefore, the results show that firms with foreign ownership performed better than domestic firms in Zimbabwe for the period 2009 – 2011. The results match prior study's conclusion of performance of foreign owned and domestically owned firms in developed, developing and transitional economies (Goethals J and Ooghe H. 1997, Khawar 2003, Douma et al. 2003, Gunduz 2003, Isik 2003, and Akimova et al. 2004).

The research provided some evidence of foreign ownership benefits on performance for firms listed on the Zimbabwe Stock Exchange. The benefits include the ability by foreign owned firms to monitor or control or give incentives to managers who manage the firm and avoiding initiatives reducing to corporate values. Another benefit is the transfer of new technology by foreign firms generating savings on operating expenses.

Foreign ownership and firm profitability

This study has found out that foreign owned firms perform better than domestically owned firms on the Zimbabwe Stock Exchange. It can be noted from the study that purely foreign firms have high profitability as indicated by return on assets, return on equity and operating profit margin. A good example is Barclays which despite the effects of the recession faced in Zimbabwe posted much better returns though it made a loss in 2009. The same can be said of British American Tobacco and Standard Chartered Bank.

On the other hand, largely domestically owned firms like Hunyani Holdings made losses up to the year 2011 despite an improvement in economic conditions. This translates into negative return on assets, return on equity and operating profit margins.

The foreign owned firms performed better under harsh economic conditions of the year 2009 where domestically owned firms were struggling to achieve a minimum level of profitability. For example Barclays had a return on assets of 0.011 which is favourable given the prevailing economic conditions; on the other hand Art Holdings which are largely domestic had a negative return on assets of - 0,054. This then shows that foreign owned firms have better disaster relief measures and given their financial muscle they can re-capitalise their firms quickly.
Thus it can be concluded that foreign owned firms perform better than domestically owned firms. This may be attributed to availability of funds from parent company and expertise that are hired by foreign owned firms.

Foreign ownership and leverage

Leverage is the proportion of debt to equity. It can be seen from this study that domestic firms have higher leverage ratios than predominantly foreign owned firms. This may be attributed to the fact that domestic firms do not have enough equity to finance the business hence they rely on borrowing. High leverage means that the firm has a high probability of being solvent.
Thus according to the research findings of this study locally owned firms have a higher probability of being solvent than foreign owned firms. On this note, literature has it that Renaissance Merchant Bank was liquidated after failing to pay its creditors. Renaissance is a predominantly locally owned bank. Thus the findings of this study reflect what is happening in real world.

Foreign ownership and stock market performance

Figures for the second half of 2009 show that, on average, 40 percent of the funds invested on the ZSE belonged to foreigners (Zimbabwe Stock Exchange). By year end, more than 4,5 billion shares worth US$414 million exchanged hands on the local bourse between February 19 and December 31 2009. The rise in participation by foreign investors on the ZSE was enhanced by the fact that local investors were constrained by lack of investment funds from the tight liquidity situation in the economy.

Furthermore, the resurrection of alternative markets, such as the foreign currency and money markets, further dampened activity by local investors on the stock market. Foreign investment participation could have been more had it not been for the high transaction costs that rendered the market illiquid. At 7, 5 percent, the costs were too high compared to those prevailing in the region, especially South Africa at around 3,5 percent.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The research findings shows that foreign owned firms outperform domestically owned firms and it is against this background that this research proposes sectarian indigenization in which percentages of domestic ownership are calculated depending on the sector of the economy and the implications that emanates from indigenization of that sector.

Recommendations

The challenge this paper ought to solve is the case of the indigenization of foreign owned firms by the government of Zimbabwe. Having found out that foreign owned firms perform better than locally owned firms, this research comes up with recommendations that the researchers feel will address the needs of the local investors and at the same time still incorporate foreign investors. It is a known fact the foreign direct investments enhances economic growth and with the Zimbabwean economy having experienced a decade long of economic down turn, economic growth is a priority.

The financial service sector

The financial services sector is a delicate part of the economy such that if changes in ownership occur rapidly the investing public may react negatively resulting in bank panics and ultimately bank runs. The banking public in Zimbabwe has widely condemned the local banks for lack of financial control after many local banks that include Barbican Bank, Royal Bank and Time Bank were put under curatorship. These banks and other local banks with the exception of Commercial Bank of Zimbabwe (CBZ) are yet to win back public confidence. As such ceding 51% ownership of foreign controlled banks may result in loss of public confidence in the banking sector as a whole, which will discourage both savings and investment and in the process bringing economic growth to a halt. Thus we propose that the financial service sector must be left out of the indigenization plan.

Mining and manufacturing sectors

These sectors are different but they have been combined in this research because we propose the same action for both sectors. Much of small scale businesses in Zimbabwe fall in either the mining sector or the manufacturing sector. Given that many local investors are small scale investors, we propose that the 51% shareholding should apply in these two sectors.

The already existing mining companies on the Zimbabwe stock exchange are Falgold, Bindura, Hwange and Rio Zim. Hwange is government owned so it is not affected by the ownership restructuring under the indigenization law. It is the perspective of the researchers that the already existing firms should cede the 51% ownership to locals over a long period of time for example the ceding of the shareholding may be completed after 20 years. This will not disrupt the capital structure of the firms immediately and will allow locals to acquire the shares gradually without straining their pockets given the fact that locals do not have adequate capital to buy the 51% shareholding in one installment.

To ensure that the locals maintain the 51% shareholding in new firms the government may reserve 51% of the operating licenses in both the mining and manufacturing sectors for locals and for any joint venture is in line with the indigenization and economic empowerment act.

The Agricultural sector

The agricultural sector is the backbone of the Zimbabwean economy and as such priority must be given to it. Given the fact that Zimbabwe successfully re-allocated its land to the black Zimbabweans, the majority of the indigenous people are involved in farming at both commercial and subsistence levels. As such, ownership in the agricultural sector should be predominantly domestic living a small percentage to the foreigners to enhance efficiency. This research's proposal for the agricultural sector is 90% for indigenous people and the remaining 10% to the foreign owners.

Suggestions for future research

This study has left many questions which ought to be answered despite being outside the scope of this study.

Firstly, there is need to explore the other aspects of firm performance other than profitability as measured by return on assets, return on equity and return on assets. It is therefore desirable that further researches are to be carried out to bridge the gap regarding other measure of performance.

The model presented in this study of sartorial indigenization is a new innovation by this research and its feasibility needs to be tested. Thus there is need for further research based on this subject.

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An analysis of the effectiveness of defensive driver training and driver retesting in the reduction of road traffic accidents among public service vehicle drivers: The case of Bulawayo Metropolitan Province.

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ABSTRACT

The study investigated the effectiveness of defensive driver training and driver re-testing in the reduction of road traffic accidents in Bulawayo Metropolitan Province. Questionnaires and semi-structured interviews were used as research instruments to collect data from 120 respondents. Findings revealed that defensive driver training and re-testing are invaluable programmes that have had a positive impact in reducing road traffic accidents. Most public service vehicle heavy vehicle drivers, big motor omnibus drivers and taxi cab drivers have complimented Government's efforts by attending the two programmes to the effect that their rate of being involved in accidents is low as shown by the study. However the majority of small commuter omnibuses that carry between 10 and 16 passengers are driven by young and unqualified drivers thus most accidents involve small commuter omnibuses and private vehicles. The study therefore recommends that defensive driver training and driver retesting be made compulsory for all drivers.

Key Words: analysis, defencsive-driving, traffic, accidents, vehicle, road.

BACKGROUND

Several road accidents involving public service vehicles have taken place on Zimbabwean roads, much to the sadness of citizens across the board. Accidents on the Zimbabwean road network have become a cause for concern. The nation is disturbed by the loss of lives on national roads due to road traffic accidents. Citizens from various sectors among them celebrities, politicians, businesspeople, educationists and the general public have lost lives or have sustained serious injuries through road traffic accidents especially those involving Public Service (PSV) vehicles. Right from the President of the nation there has been condemnation of drivers and transport operators alike.

Maunder and Pearce (1999) in their study on road accidents in Zimbabwe and Nepal stratified road accident statistics in a bid to identify the causes of accidents that involve public service vehicles. They concluded that 58% of bus accidents were classified as blameworthy (driver's fault). Blameworthy accidents led to 76% of bus fatalities and 75% of injuries. Grouping blameworthy causes as assessed by the police led to the following findings: Driver misjudgement 82%; Vehicle defect 7%; Road condition, drink/drugs, other 11%.

The authors noted that driver misjudgement, including factors such as excessive and reckless speeding, following too closely, overtaking and reversing errors, failure to give way, was the key element of blameworthy accidents as apportioned by the Zimbabwe Police. The most frequent causal features of bus accidents identified comprised poor driver behaviour, pedestrian/other road user behaviour and the mechanical condition of the bus.

Out of the findings of their research, Maunder and Pearce (1999) made the following recommendations:

- Social and psychological skills, required to be a safe and responsible professional driver, should be taught.
- Refresher driver training courses to eliminate the inevitable bad habits acquired should be encouraged.
- Awards for 'accident free' driving should be promoted.
- Medical and health are necessary for all, especially ageing, drivers.
- Enforcement of legal maximum hours should be given a higher priority

As a result, the relevant authorities then in the Ministry of Transport and Communications responded by introducing the compulsory defensive driving course and retesting for all public service drivers. Taking note of the above-mentioned recommendations was seen as a panacea to dealing with accidents involving public service vehicles. The authors noted that much as these factors increased costs they were likely to be less expensive in the longer term than the cost of human tragedy, vehicle replacement and other third party costs.

Driver re-testing is conducted by the Vehicle Inspection Department (VID), while defensive driver training is carried out by the Traffic Safety Council of Zimbabwe (TSCZ). The Government, through Statutory Instrument 168 of 2006 under the Road Traffic Act Chapter 13:11, mandated the Vehicle Inspectorate Department (VID), the Zimbabwe Traffic Safety Council (ZTSC) and the

Zimbabwe Republic Police (ZRP) Traffic to ensure safety on the roads by the implementation of certain laws and the respective regulations.

The VID is a Government Department under the Ministry of Transport and Infrastructural Development and is mandated to proffer road safety on the Zimbabwean Road Network. It employs the use of the Road Traffic Act Chapter 13:11, Road Motor Transportation Act and Ancillary Regulations to fulfil the ministry's mission of ensuring the provision of an adequate, efficient, safe and reliable transport system. The TSCZ is a parastatal established in terms of section 3 of the Traffic Safety Council Act (Chapter13:17) and operates under the same auspices of the Ministry of Transport and Infrastructural Development. The council is mandated with ensuring road safety through the implementation of various programs such as defensive driver training and traffic safety campaigns.

This study reviewed the human factors theory which argues that most road accidents are a result of human error. Molinero et al (2009) note the logic behind this theory is that accidents can be attributed to a chain of events ultimately caused by human error. The chain of events can be as a result of the following factors;1. Overload (due to environmental factors such as noise, distraction, or internal factors, personal problems, emotional stress or situational factors such as unclear instructions, risk level), 2. Inappropriate response/compatibility (like identifying hazard but not correcting it, remove safeguards, and ignoring safety), 3. Inappropriate activities (performing tasks without the requisite training, misjudging the degree of risk involved with a given task).

Assum (1998) weighs in with support for this theory by stating that human factors are often the most important road accident cause. Driving too fast, driving under the influence of drugs or alcohol, other reckless driving, inattention to other road users, overloading vehicles with goods and people, and driving for too many hours undoubtedly contribute significantly to road accidents.

Objectives

The broad objective of the study was to investigate the impact of measures implemented by government to curb road traffic accidents involving public service vehicles.

Specifically the study sought:

1. To determine whether Defensive Driver Training reduces the chances of a driver being involved in an accident.
2. To establish whether Driver Re-testing improves a driver's competency.
3. To recommend possible solutions likely to help in reducing road traffic accidents.

Methodology

The study adopted the descriptive survey design. The descriptive survey design entails the process of collecting data at a particular point in time with the intention of describing the nature of existing conditions. Descriptive studies are primarily concerned with finding out, "what is". They seek to describe accurately the characteristics of an individual, a situation or group and then determine the frequency with which one event is associated with another, (Babbie, 1975). In this study the information sought was on road traffic accidents, their causes, and whether the drivers involved underwent defensive driving and retesting. This type of survey uses direct observation, questionnaires and interviews to collect data. The approach adopted sought to gather both qualitative and quantitative data mainly using questionnaires and interviews.

The population of this study was all public service vehicle drivers and private vehicle drivers within Bulawayo Metropolitan Province. These include omnibus drivers, taxi-cab drivers, heavy goods vehicle drivers, and minibus drivers. In this context the population also included traffic in transit, for example, heavy haulage trucks from Zimbabwe to Zambia passing through Bulawayo or traffic from Plumtree to Harare passing through Bulawayo.

The sample size for this study was 123 respondents who represent constituencies relevant to this research. The table below shows the various categories of the selected sample. 123 respondents were selected on the basis of the researchers' own knowledge of the population, its elements and the nature of the research aims.

Table 1. Sample of Respondents

RESPONDENTS	NUMBER
Omnibus drivers (17 to 75 passengers)	20
Taxi-Cab drivers	20
Heavy truck drivers	20
Minibus drivers (10 to 16 passengers)	40
Private vehicle drivers	20
Zimbabwe Traffic Safety Council (Bulawayo Director)	1
Zimbabwe Republic Police Traffic (Officer Commanding Traffic Southern Region)	1
Vehicle Inspection Depot (Senior Inspector)	1
Total	123

The researchers used non-probability quota sampling in selecting 120 drivers within Bulawayo Metropolitan Province. Johnson and Joslyn (1995) observe that in quota sampling, elements are sampled in proportion to their representation in the population, and thus it is similar to proportionate stratified sampling. Given that there are more public service minibus vehicles it seemed laudable to include more minibus drivers. The difference with stratified sampling was that the sample was not chosen in a probabilistic manner.

The researchers also used non-probability purposive sampling in selecting the respondents from the VID, ZRP Traffic and ZTSC. These are key respondents to the research especially with regards to policy implementation on the subject under study. The police, VID and ZTSC officers are players visibly active in both the operations and regulation of the transport sector countrywide and are constitutionally mandated to do so.

Questionnaires made of both closed and open-ended questions were distributed to the 120 drivers. Questionnaires mainly sought to find out drivers' experience, re-test status, whether they are defensive certificate holders or not, and their opinions on both retesting and the defensive certificate programme. Semi-structured interviews were also conducted with officials from the police, VID and ZTSC. Interviews were used by the researchers to complement the questionnaires especially on

questions directed to those who were involved in road traffic accidents. The researchers targeted Renkini long-distance bus terminus, Nkulumane long-distance bus terminus, TM Hyper taxi rank, Egodini local/long distance bus terminus, the Bulawayo-Beitbridge highway and the Bulawayo-Harare highway for selection of participants and distribution of questionnaires.

Results

Response Rate

A total of 120 questionnaires were administered to respondents and of these only three were not answered, showing a response rate of 97.5%. The high response rate could be attributed to the method employed to collect data. One hundred questionnaires were served to the respondents in person and collected immediately upon completion. The remaining 20 questionnaires for collecting information from those involved in accidents were left at Bulawayo VID police-post and three of them were not completed.

Table 2. Distribution of respondents by age. N =117

Age Range	F	%
15 – 24	26	22.22
25 – 34	31	26.5
35 – 44	36	30.77
45 – 54	19	16.24
55+	5	4.27
Total	117	100

The study revealed that the majority of drivers of taxi cabs, heavy vehicles and motor omnibuses that carry more than 17 passengers are above 25 years of age. However most minibuses that carry between 10 and 16 passengers and few taxi cabs are being driven by under-age drivers. Their age ranges from 18-24 years, and these young drivers do not have 5 years driving experience to qualify them for retesting.

Table 3. Commuter Omnibuses (10-16 passengers) Drivers with defensive driving certificate and re-test. N =40.

Respondents	Frequency	Percentage (%)
Holder	8	20%
Non-Holder	32	80%
Totals	40	100%

The responses as shown in table 3 show that only 20% of commuter omnibuses that carry 10 -16 passengers attended a defensive driving course and re-test. The rest, that is 80% do not hold a defensive driving certificate or re-test.

Table 4. Motor omnibuses (17-75 Passengers) Drivers with defensive driving certificate and re-test. N = 20

Respondents	Frequency	%
Holder	19	95
Non-Holder	1	5
Totals	20	100

Table 4 show that 95% of the drivers who drive big omnibuses underwent a defensive driving course and also a re-test. The majority of the drivers are mature between the ages of 34 and 54 years.

Table 5. Taxi cab drivers with defensive driving certificate and re-test. N=20

Respondents	Frequency	- %
Holders	12	60%
Non-Holders	8	40%
Totals	20	100%

Table 5 shows that 60% of taxi drivers were trained in defensive driving and were also retested. Findings revealed that non-compliance by some taxi drivers was due to the fact that the drivers are

also the owners of the taxis and therefore do not have a push from anyone because they are self employed.

Table 6. PSV Heavy vehicle drivers with defensive driving and re-test. N=20

Respondents	Frequency	%
Yes	19	95%
No	1	5%
Totals	20	100%

Table 6 shows that PSV Heavy vehicles drivers comply with the requirements of defensive driving and re-testing. Most of the drivers are professional drivers who have a lot of experience. These drivers transport heavy load and usually travel long distances and in most cases cross borders resulting in them meeting different laws and law enforcement agents of various countries. Furthermore, the loads are insured and in case of accident the driver must be found with all the requirements otherwise the insurance company will not compensate.

Opinion of drivers on defensive driving and re-testing

Most PSV drivers concurred that defensive driving is effective but were of the view that re-testing was not at all helpful in reducing the rate of accidents. Their argument was that retesting was just a way of Government to make money while making life difficult for them. Driver re-testing was sighted as a useless programme that added no value to driving. The drivers condemned the re-testing process in that the test did not differentiate between an experienced driver and one who was undergoing a road test for the first time. They argued an experienced driver will fail a re-test not because of incompetency, but in most cases due to other factors such as nervousness or unprofessionalism on the part of the examiner. Of major concern was the use of, for example, an articulated hose without its trailers during a re-test but in normal circumstances the same driver would drive the said articulated horse with two loaded trailers. Findings from ZRP and VID officials revealed that driver retesting is unpopular among drivers not because it is not useful, but it is a process that takes time, irrespective of whether one passes the test or not. If one fails the retest, they have to rebook, which demands more time and money. At the same time by going back to work without the necessary papers they risk being fined by the police. If one passes the test, they have to endure the whole year waiting for their metal licence disc. In the meantime they would have

to make do with a barrage of documents including the national id, certificate of competency and the medical certificate.

Assessing the major cause of road traffic accidents in Bulawayo

A total of 46 vehicles involved in road traffic accidents in and around Bulawayo were taken to VID Bulawayo depot for inspection. The accidents happened from the 9th of July 2011 to the 9th of August 2011. Of the 46 reported accidents there were 18 public service vehicles and the remaining 28 were all private vehicles. Figure 1 below shows that about 60% of accidents that happened involved private vehicles. Commuter omnibuses that carry between 10 to 16 passengers also had a high rate of accidents. However, not all drivers who were involved in accidents were able to complete questionnaires. Only 17 respondents completed the questionnaires.

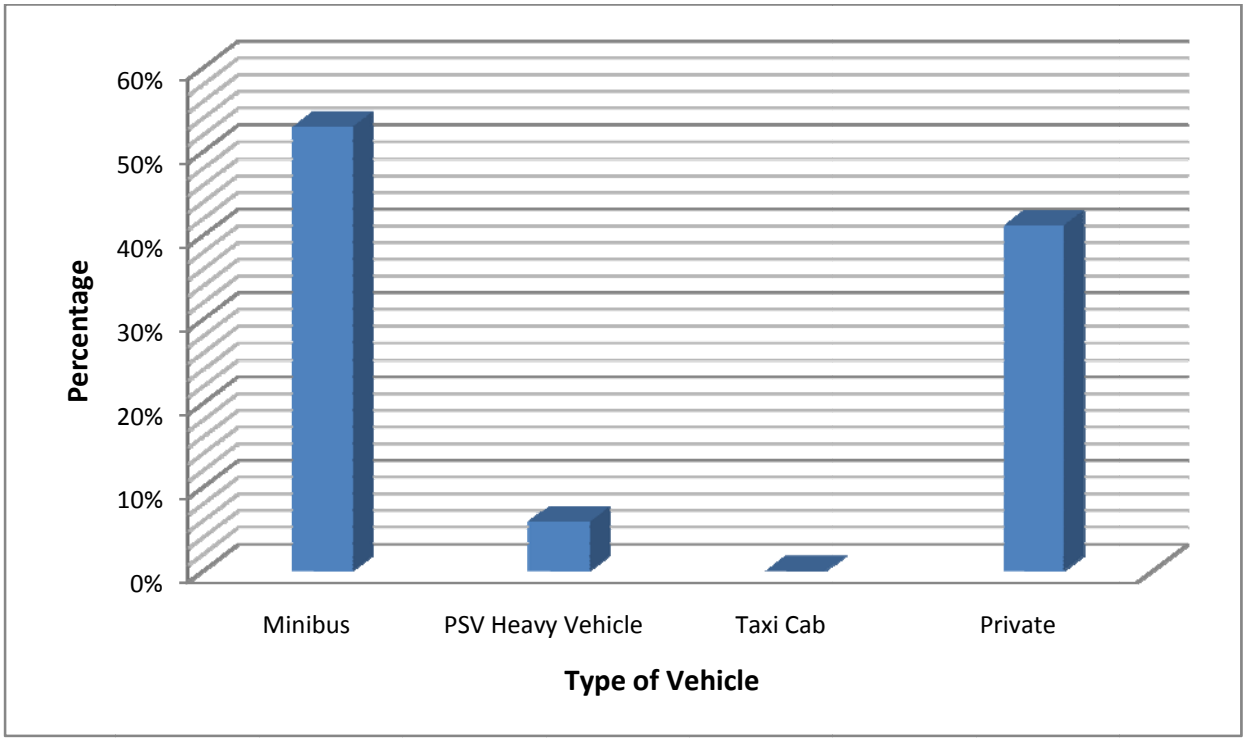

Figure 1: Bulawayo road accidents statistics July to August 2011.

Figure 1 shows that the majority of respondents were drivers of commuter omnibuses (52.94%) and private vehicles (41.18%). The response rate was high for commuter omnibus drivers because commuter omnibuses are business vehicles and owners usually make a quick follow-up to reduce downtime. The response rate was also high for private vehicles because the owners do not like to stay for a long time without their vehicles.

Table 7. Drivers with defensive driving and re-test involved in accidents. N = 8

Respondents	F	%
Holders	1	12.5
Non- Holders	7	87.5
Totals	8	100

Table 7 shows that about 87.5% of commuter omnibuses drivers did not do a defensive driving course. They are not complying with the law that provides that all PSV Drivers must hold a defensive driving certificate.

Table 8. Drivers with defensive driving and re-test involved in accidents

Respondent/Type of Vehicle	F
Commuter omnibus	1
PSV Heavy Vehicle	1
Taxi Cab	0
Private	0
Total	2

Table 8 shows that all private vehicle drivers involved in accidents in and around Bulawayo during the period under study did not have defensive driving certificate and re-test. However these requirements are not compulsory for private vehicle drivers. The PSV heavy vehicle driver and one commuter omnibus driver involved in accidents had the required documents.

Table 9. Drivers without both defensive and re-test involved in accidents. N=15

Respondent/Type of Vehicle	F
Commuter Omnibus	8
PSV Heavy Vehicles	0
Taxi Cab	0
Private Cars	7
Total	15

Table 9 shows that 8 commuter omnibus drivers and all the private vehicle drivers did not have neither defensive nor re-test. The study established that the majority of commuter omnibus drivers

are under age therefore do not qualify for PSV driving and as result are not eligible for re-test. Most of the PSV Heavy Vehicle drivers hold both defensive and re-test making them more competent in avoiding accidents.

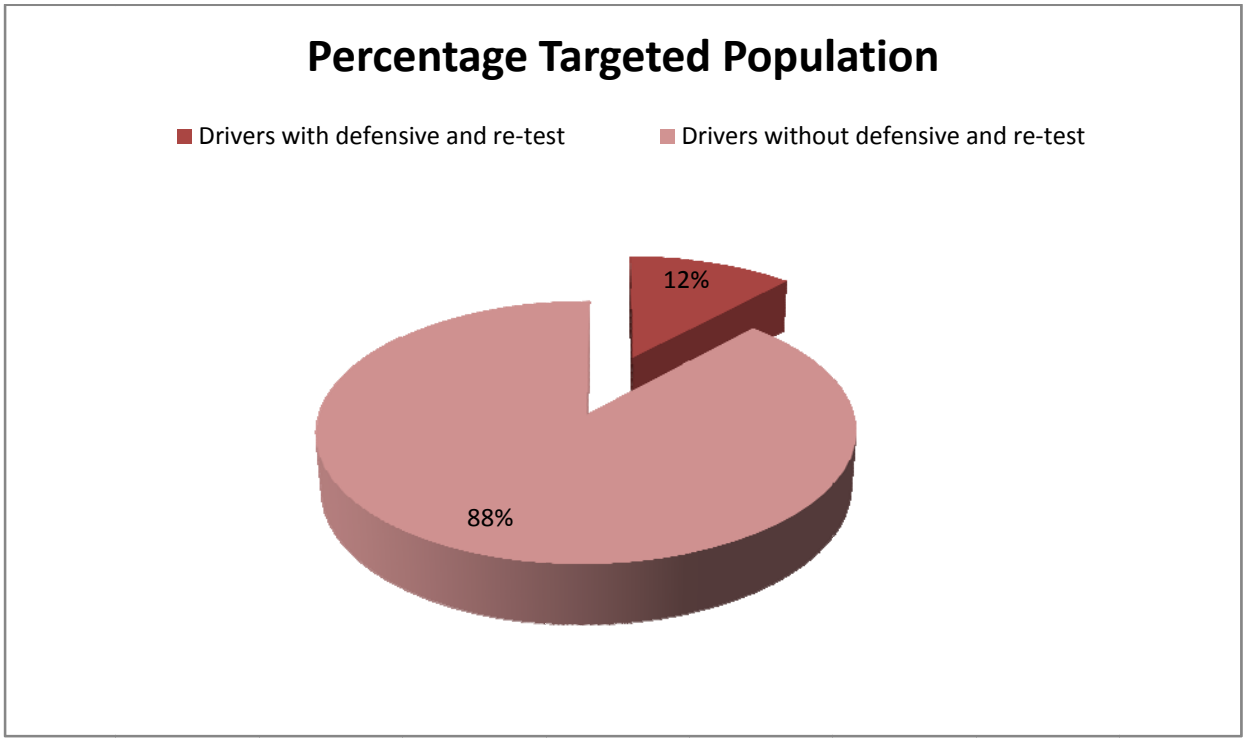

Figure 2: Drivers with and without both defensive certificate and retest.

Figure 2 shows that only 12% of drivers involved in accidents in and around Bulawayo have both defensive driving and re-test, that is, 88% do not have the requirements for driving public service vehicles.

Establishing whether defensive driving and re-testing improves the competency of a driver thereby reducing chances of being involved in accidents.

The study established that defensive and re-testing improves a driver's competency in driving thereby reducing his or her chances of being involved in an accident. The competency of a driver is likely to improve since the driver goes through the same basic and rigorous test which is similar to those undertaking a road test for the first time. It also improves competency in that going through the same test for the second time is likely to sharpen the skills and rejuvenates consistency. That is, if the driver was driving well for the past five years the general belief is that his or her driving habit will change. So re-testing was introduced to assess and reinforce his or her competency. However

some of the drivers fail not because of incompetency but due to other factors such as panicking, faulty vehicle and inconsistency on the part of the driving examiners.

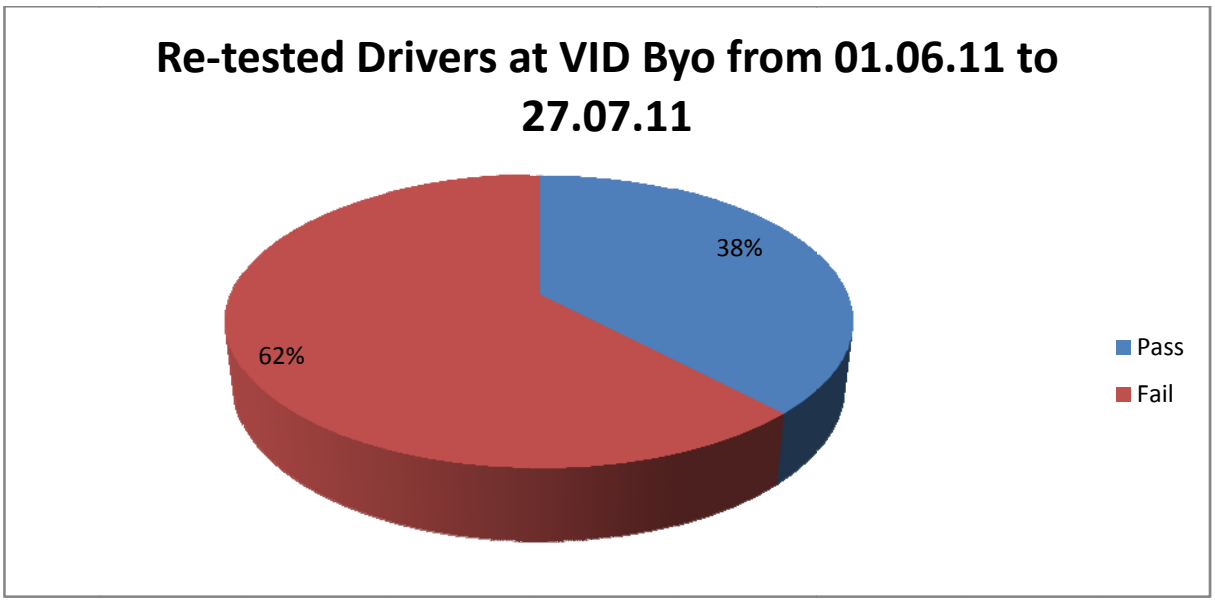

Figure 3: PSV drivers retested at VID Bulawayo from June to July 2011

Out of 47 PSV drivers who went for re-testing at VID Bulawayo as from the 1st of June 2011 to the 27th of July 2011; 18 passed while 29 failed, indicating a pass rate of 38.3%. It is a matter of concern when a driver fails a test he or she has passed before and in addition has acquired some experience. This implies that the driver's competency might have deteriorated with time and age, or one is forced to assume that they may not have initially acquired their licenses the 'right' way. The requirements for a re-test are a medical certificate from a qualified Government medical practitioner, proof of continuous driving for five years and a valid defensive driving certificate. Therefore, it is most likely that at times drivers fail not because of incompetency but things such as nervousness, panic and faulty vehicle.

When undergoing a re-test the driver starts by reversing into a restricted area, for example drums, and then goes on gradient control or hill-start where he or she is now required to stop the vehicle and then move without rolling back. Failure on either hill-start or drums results in the test being terminated. However if the driver is successful in both drums and hill-start he or she then goes on town driving or assessment.

Table 10. Breakdown of re-test results

Where failed	Frequency	%
Drums	13	27.66
Hill-start	9	19.15
Town driving	7	14.89
Pass	18	38.3
Totals	47	100

Most of the PSV drivers, that is, 27.66% failed to reverse into the drums while 19.15% failed gradient control, and the remaining 14.89% failed in town driving. The majority of drivers fail on drums and hill start. This is in spite of the fact that the drivers have at least five years continuous driving experience and therefore are expected to have little or no problems with reversing and hill start. On the other hand those who fail town driving fail because of various reasons such as pedestrians, zebra crossing, give ways, stop signs and carriage way markings. Failure to obey road rules results in immediate fail of test. It follows then that a driver who fails a re-test is not competent enough although he or she is a holder of a valid driver's licence and in most cases currently employed. The blame cannot be put on the examiner's way of assessing because most of drivers failed either to reverse into drums (27.66%) or hill start (19.15%) and very few, only 14.8% who failed town driving needed the examiner's judgement. It can be argued that examiners gave fair test. Many drivers pass the re-test after several attempts and in that case it can safely be said that re testing of drivers improves their competency because they would have polished certain areas that caused them to fail on their first attempts.

CONCLUSIONS

The study established that defensive driver training improves a driver's competency hence reduces their chances of being involved in an accident. The majority of the PSV heavy vehicle drivers, big motor omnibus drivers and taxi cab drivers meet all the requirements of the PSV driving. Most of them went through defensive driving and as a result they are not always involved in accidents as compared to small commuter omnibuses whose drivers are unqualified. All the eight PSV drivers who were involved in accidents did not have defensive driving implying that to some extent defensive driving reduces the chance of a driver being involved in an accident.

The researchers also established that driver re-testing improves a driver's competency in driving. This is because the re-test is conducted in the same manner as for a new learner driver undergoing a

road test for the first time. Re-test is done to experienced drivers who have been continuously driving for at least five years and thus re-test ensures that drivers remain consistent, and they are able to keep abreast with the changing driver environment. It can be equated to a refresher test.

The research revealed that most accidents involve small commuter omnibuses that carry between 10 and 16 passengers. They are mostly driven by unqualified drivers who in most cases are below the age of twenty five years. These accidents are a mostly as a result of human error such as over speeding, racing of robots to meet targets and driving under the influence of alcohol, thus giving credence to the human error theory.

RECOMMENDATIONS

Based on the conclusions made from the research, the following recommendations are made to policy makers, law enforcement agencies and other stakeholders so that they play a more positive role in reducing the rate of road traffic accidents.

Defensive driver training is an important programme that must be continued as research has shown that drivers who underwent defensive driving have less chances of being involved in road traffic accidents. Although the opinion of many drivers is against re-testing the researchers suggest that re-testing of PSV drivers must not be dropped because it adds value to their driving. Most of the drivers are just afraid of a test just like any person and they would want to avoid the retest. However, many drivers may be failing the re-test not because of incompetency but fail due to other factors such as panicking and faulty vehicles.

Many accidents that are happening involve drivers without defensive driving skills. The drivers are mostly private drivers and commuter omnibuses that carry between 10 to 16 passengers. The law is explicit with respect to the minimum age for PSV drivers which are between 25 years and 70 years. However, the majorities of the small commuter omnibuses drivers are under age and do not either have defensive or re-test. They seem not to be afraid of the law because when caught they just pay a small ‘fine’ and proceed. The researchers suggest that the law be amended so as to bring to book the owners of the vehicles that are driven by unqualified drivers because they are the employers. They should be made to account for entrusting their public service vehicles into the hands of unqualified drivers.

Private vehicles are second after small commuter omnibuses when it comes to accidents. The researchers suggest that defensive driving must be made compulsory for every driver because all drivers use the same roads and they therefore affect each other.

Defensive driving is a higher level of driving and it sounds unwise to enroll a person who is not yet a qualified driver. The researchers therefore recommend that only those drivers with at least one year driving experience must be allowed to attend a defensive driving course. Furthermore, the defensive driving certificate expires after a period of four years while a learner's license expires after one year and in such a case it is possible to have holders of DDC certificates whose learner's licenses have expired. Such people may end up cheating and use the DDC certificate claiming to have forgotten their licenses at home.

It is also recommended that driver re-testing must be done after thorough vetting of traffic offences so as to weed out habitual traffic offenders. At the present moment there is no collaboration between the various stakeholders. For example, Traffic Police, Central Vehicle Registry and VID must be networked so that before a driver is re-tested, his or her record is checked. In addition if a driver is ticketed for any offense the record should reflect both at VID and CVR.

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Social Capital and the Informal Vendor Economy In The Dollarized Zimbabwe. A Case of Mucheke Suburbs In Masvingo Urban.

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ABSTRACT

The dollarization of the Zimbabwean economy after a decade of economic doldrums has led to a hive of economic activities in urban space. This research analysed the role of social networking in the sustenance of the livelihoods of informal vendors in Masvingo urban. It also examined the challenges faced by informal vendors in sustaining their livelihoods and the ways used by informal vendors to ameliorate their situation. Informal vending is a major livelihood strategy despite being relegated to the periphery. Social capital becomes valuable in sustaining vendors' livelihoods and transcending the problems they face in sustaining their livelihoods. This study accentuated the need to promote, educate and empower informal vendors to enjoy the gains of the informal sector in the larger economy. This ethnographic study was purely qualitative; utilising unstructured interviews, focus group discussions and secondary sources to harvest data, while participants were chosen on the basis of convenience.

Key Words: **Social capital, informal vending, dollarization, livelihoods.**

INTRODUCTION AND BACKGROUND TO THE STUDY

The dollarization of the Zimbabwean economy in 2009 has had tremendous impact on the growth of the informal sector in general and street vending in particular. The exponential growth of the sector requires novel ways of transcending the daily catastrophes marring the welfare of informal vendors. Taking the city of Masvingo as a case study, this study's fundamental foundation was rooted on the examination of the role of social capital in the sustenance of informal vending in Masvingo urban. The study was also situated in an on-going evaluation of the challenges faced by informal vendors in sustaining their livelihoods and the assessment of the coping strategies used to transcend those challenges. Informal vending in this study is synonymised with street vending which is referred to in different names like the underground economy, black market, illegal economy, irregular economy, among many others. For working purposes, social capital shall be used in this research to refer to resources grounded in durable exchange-based networks or relationships of persons (Bourdieu, 1986) (1).

Losby et al (2002) (2) contend that the informal sector is as old as industrialisation, although it has not received a close scrutiny especially in the context of sustainable cities. As such, Chirisa (2008) (3) noted that the informal sector warrants constant theoretical interrogation if effective and long lasting policies in relation to the sector are to be established. Mitullah (2004) (4) opinesthat the informal sector is the backbone of African economies although it is relegated to the periphery when it comes to policy issues. Adiko and Anoh, (2003) (5) noted a sexual division of labour where men participate more in the formal sector while women dominate the informal sector. Gukurume and Nyanga (2011) (6) noted that the informal sector also attracts children who reconcile work and school in endeavours geared toward livelihood sustenance. This is sufficient evidence to authenticate the notion that many urban cities sustain themselvesthrough the informal sector. It is imperative to note that research on informal vending mainly focused on issues of actors negating the crucial role of social capital in circumventing the challenges faced by the actors in sustaining their livelihoods. This study becomes illuminating in its ability to anchor emphasis on the above mentioned knowledge gap.

Focusing on policy and associational issues, Mitullah (2004) noted that few innovative cities in Africa, such as Durban, have initiated programmes that integrate street vendors in urban development. Others, such as Nairobi, have accepted the operations of street vendors by setting aside specific lanes outside the central parts of the city for vendors, but are still to have specific policy relating to the informal economy and street trade in particular. Although relocation of street traders is a major step, the sites still lack services, while others are located away from busy areas and the vendors are reluctant to move to these areas since they jeopardise their chances of succeeding in the said business. Dube (2011) (7) propounded that because of the informality tag associated with woman cross-border trade and other informal activities, government programmes to assist women cross-border traders in Masvingo have been very slim. Consequently, most women cross-border traders resort to social networking as a way of learning the germane business etiquette. Abe (2011) (8) noted that despite its attendant benefit, informal vending has been plagued by the dilemma of double tragedy in Nigeria generally and Ibadan in particular. The examination of the experiences of street vendors in vast periods of political transition in Malawi by Kayuni and Tambulasi (2009) (9) brought to light the idea that legal structures in relation to informal vending depend heavily on the political will of the top echelons of the government. Having given valuable snap shots of policy and associational challenges marring the effectiveness of informal vending, the

researches under review fell short of specificity on the recurrent theme of this study, that is,the role of social capital in sustaining the informal vendor economy.

Studies have also indicated that the formal urban economy has lost glamour in favour of the informal one as actors have taken advantage of its easy of entry (Chirisa, 2007) (10). With respect to Zimbabwe, despite efforts directed towards cleaning urban areas of its informal activities through Operation Murambatsvina in 2005, there is an increase in the informal sector activities (International Crisis Group (ICG), 2005) (11). The informal sector activities have resurrected, re-emerged, and even become more relient (Dube and Chirisa, 2012) (12), taking new shapes in scope, dimension and variations leaving a clear handwriting on the wall that the bulldozer cannot move informal vendors from the street. Nocturnal vending has been established as the safest mode of operation where the predator (police) would have slept. Crackdowns, clean up campaigns and raids are the main tools employed by city managers in a bid to maintain orderly and aesthetic city environments although corrupt activities are used by municipal police and Zimbabwe Republic Police (ZRP) as they solicit bribe in their self-enriching spree induced by lawlessness in Zimbabwe (Brown, 2006) (13). Little was, however, done in assessing the role of social capital in circumventing the challenges faced by informal vendors. Thus, this study laid specific emphasis on this subject of negation in most researches.

STATEMENT OF THE PROBLEM

The informal sector is as old as industrialisation, although it has not received a close scrutiny especially in the context of sustainable cities (Losby et al, 2002). As such, the sector warrants constant theoretical interrogation if effective and long lasting policies are to be established (Chirisa, 2008). While acknowledging that the booming of the informal sector was something not unheard of prior to the period of dollarization in Zimbabwe, this study contends that dollarization has witnessed the growth of this sector at an exponential rate. With the increase in the number of participants, novel challenges to informal vending emerge requiring novel solutions, especially considering that informal vendors are still considered shoddy dealers in Zimbabwe's legal framework (Dube, 2011). The role of social capital in sustaining the informal vendor economy is not given sufficient specificity in previous researches giving impetus to the study in question. More so, voluminous studies on the informal sector in general and street vending in particular were carried out on a global scale. Few researches in existence on the Zimbabwean urban terrain were situated in the capital-Harare, with the city of Masvingo coming to the vicinity of very few researchers. Research on street vending in Zimbabwe is also saturated in the pre-dollarization era where as the adoption of multicurrency (dollarization) in 2009 ushered the nation into novel

economic, social and political terrains sufficient for bringing a change to the informal sector in general and street vending in particular. This research was situated in an on-going examination of the role of social capital in the sustenance of the informal vendor economy in the dollarized Zimbabwe, a largely invisible area in most researches on the subject. A holistic approach was taken to include the challenges faced by actors in the sector and the coping strategies adopted to ameliorate the challenges. Considering the paucity of research on such issues in the dollarized Zimbabwe, this research offers enough lenses for understanding the experiences of informal vendors in the current era of dollarization.

OBJECTIVES

-To evaluate the challenges faced by informal vendors in sustaining their livelihoods.

-To examine the coping strategies used to deal with the problems faced by informal vendors.

-To examine the role of social capital in the sustenance of informal vending in Masvingo urban.

THEORETICAL FRAMEWORK

This research utilised Bourdieu's theory of structuralist-constructivism, his postulations on the dialectics of habitus and field as well as social capital taking centre stage. Bourdieu (1979) (14) was largely concerned with the dichotomous relationship between the habitus and the field, which he saw as operating in dialectically reciprocated manners. The field conditions the habitus; while the habitus structures the field making it something that is meaningful. This theory was more appropriate to this study since it explains how informal vendors deal with their social world by adopting strategies that help them transcend the problems they face in utilising informal vending to sustain their livelihoods. Bourdieu (1979) noted that the habitus refers to a set of dispositions created and reformulated through the conjuncture of objectives, structures and personal history of the people in question. It was apparent in this study that people's disposition largely inform the coping strategies they adopt to deal with their problems. The field refers to an arena of contestations and struggles in a network of relationships, in this case, areas of struggles for survival and strategies that are adopted in circumventing the challenges faced by informal vendors in carrying out their daily activities.

Bourdieu's thesis provides a momentous analytical milieu for understanding the dialectical relationship between the structure, in this case the challenges faced by informal vendors as well as the legal framework on informal vending, and agency which denotes the strategies employed by informal vendors to deal with their problems. For Bourdieu (1986), social capital is the sum total of

all the resources, virtual or actual, that accrue to an individual or group by virtue of possessing a durable network of more or less institutionalized relationship of mutual acquaintance and recognition.In this study social capital is used to underpin all the networks and relationships manipulated by informal vendors to transcend the daily conundrum posited to their livelihood strategy.

According to Bourdieu (1979) the structure constraints and enables at the same time. In the theory of structuralist-constructivism, he reflects the idea that structures constrain and circumscribe volition, but at the same time people use their capacities for thought, reflection and action to construct social and cultural phenomena. He adds that social and cultural structures also create options, possibilities and paths for creative action and for the construction of new and unique cultural and social phenomena. In other words agents (informal vendors) are not passive recipients of external structural stimuli, but their reflexivity enables them to employ multifarious techniques of adjustment to cope with the prevailing situation. This research unearthed scores of strategies adopted by informal vendors as they thrive to survive in situations of turmoil posited to them by the legal framework of Masvingo urban. The theory of structuralist-constructivism was instrumental in identifying how informal vendors manipulate social capital and other strategies to overcome the challenges they face in sustaining their livelihoods in the dollarized Zimbabwe.

The study was grounded inthe qualitative methodology on the account that it was hunched upon people's perceptions on the role of social capital in the sustenance of informal vending, the challenges faced in such endeavours as well as the coping strategies employed, all of which are rather unquantifiable. The study was based on an ethnographic field work involving fifty-two participants selected on the basis of convenience in Mucheke high density suburbs in Masvingo urban. The sample size was based on saturation rather than representativeness since the goal of qualitative researchusually is not to make inferences about the underlying population, but to attempt to obtain insights into particular educational, social, and familial processes and practices that exist within a specific context (Connolly, 1998) (15). In this case the goal was to obtain deep insights on the role of social capital in the sustenance of informal vending. Unstructured interviews, focus group discussions and secondary sources were triangulated in harvesting data to gain an in-depth understanding by corroborating different narratives on peoples' perceptions on the issues under investigation.

Unstructured interviews are one to one in-depth interviews which the researcher (interviewer) used to gain valuable information from discussing issues with participants (interviewees). The interviewer prompted the interviewees to give more information by joining in the interviews,

discussing what he thinks on the topic. Body language was utilized by the interviewer to gain more understanding from unspoken words. Twenty-four (24) people were interviewed, two (2) of whom were members from Small and Medium Enterprises Development, two (2) others from ZRP, three (3) from Masvingo City Council while the rest were informal vendors. The power of Focus Group Discussions (FGDs) in the research was in providing rich and spontaneous information by triggering multi-vocal perceptions on the challenges faced by informal vendors in their day-to-day operations, how the challenges are dealt with and the value of social capital in the sustenance of informal vending in the dollarized Zimbabwe. The tool also helped to check and balance ideas coming from unstructured interviews since the presence of others in most cases helps to authenticate views raised by other respondents. Four (4) FGDs of seven (7)people each were conducted, one for males, one for females, the other one for children and the last one for males, females and children so as to capture the ideas of all categories of participants in informal vending. The ethnographic approach enabled the researcher to easily conduct Focus Group Discussions and in-depth interviews. Secondary sources of data were of paramount significance in providing written and therefore easily accessible information on the challenges faced by informal vendors as well as the ways used to ameliorate them. Consent was always sought and the assurance of privacy and confidentiality given to ensure safety of participants since the research would unravel corrupt activities by legal watchdogs from the police and municipality.

PRESENTATION AND DISCUSSION OF FINDINGS

Presentation and analysis of data obtained from this research followed a thematic format. Bourdieu's theory of structuralist-constructivism and related literature offered the required analytical lenses to the discussion of findings.

THE HISTORY OF INFORMAL VENDING AS A LIVELIHOOD STRATEGY IN MASVINGO URBAN

Street vending in Masvingo urban, like in many African cities, is as old as industrialisation. At different epochs in the history of the city, the informal vendor economy was adopted as a livelihood strategy by many households living in abject poverty. Informal vending which is understood as the obverse of the normal sector in terms of being unregulated, unregistered and untaxed, is just one component of a wide array of activities doomed illegal, and therefore informal, inclusive of illegal transport operating, money changing, informal settlements, urban agricultural activities, educational informality and unregistered small enterprises. To understand the impact of dollarization to the growth of the informal sector, it is essential to trace the background history of informal vending in

Masvingo urban. Wild (1992) (16) noted that even in colonial Zimbabwe informal vending was prevalent. All sorts of trade and self-employment were referred to as 'businesses' and the participant 'businessman'/'businesswoman'. It was established from the same source that businessman or businesswoman during the colonial era travelled from their 'respective kraals' to sell hawk fowls, eggs, pumpkins, grains, etc. This is enough evidence to suggest that the recent boom in the informal sector in general and informal vending in particular is a result of decades of evolution from the colonial period despite the variance in the terms used to refer to the sector. The same was also observed by Losby et al (2002) who purported that the informal sector is as old as industrialisation although it has not yet received a close scrutiny in the context of sustainable cities.
Despite that Structural Adjustment Programmes (SAPs) aided the growth of the informal sector in Zimbabwe; informal vending in Masvingo urban began to boost a new swell than ever at the beginning of the new millennium as a result of increased inflation and unemployment rates. Fruits and vegetables were the most known products in the informal sector prior to the new millennium, but thereafter, more products penetrated the market including grains, clothes, electrical gadgets, kitchen ware and hardware, among a wide array of commodities. A certain participant clarifying the multiplicity of products on the market notedthat, "*change chasarakutengeswamunhuchete"* (only a human being could not be sold). This prompted the government to initiate a clean-up campaign called Operation Murambatsvina in 2005 which contributed little in bringing the informal sector to a halt. In less than half a decade later, the street was flooded again with informal vendors zealous to eke a living from the easily accessible sector indicating the ineffectiveness of brute force in bringing informal vendors to their heels. This was largely a result of the Consumer Council of Zimbabwe's 2008 price control measure which led to the succumbing of quite a considerable number of indigenous companies thereby worsening the unemployment situation. Inflation rates also skyrocketed to unanticipated magnitudesinjuringthe affection of those who remained in formal jobs. In the face of such catastrophes, no coercive measure could move informal vendors from the street.

The multicurrency system, termed dollarization in this study due to the dominance of the United States dollar over the South African rand as well as the Botswana pula, was adopted in an environment where the formal sector had been eroded and the informal sector assumed its zenith. Dollarization brought the hopes of economic rejuvenation paving the way for all government departments to resume operation. Consequently, the registry's department under the ministry of Home Affairs began to clear backlogs on passports and made the Temporal Travel Documents easily accessible and cheaper. The South African Visa waiver of April 2009 also compounded the

situation since many people could easily migrate for business purposes. Since accessing formal jobs was still a far cry for many unemployed youths, the informal sector became a fertile ground for livelihood sustenance. Like the period prior to dollarization, a wide array of commodities existed on the market, but food staffs especially meat and meat products were dominant. Many cross-border traders specialise in chicken cuts, chicken feet, chicken offal, eggs, sausages, among many related commodities.

DOLLARIZATION AND THE EXPONENTIAL RISE OF THE INFORMAL SECTOR

While acknowledging that the booming of informal vending was something not unheard of prior to this period, this study contents that dollarization has witnessed the growth of this practice at an exponential rate. It emerged from the study that the upsurge in informal vending was catapulted by the forces of urbanisation. As opposed to counter urbanisation which assumed its zenith during the period of Zimbabwe's economic quandary, dollarization revitalized the economy thereby rejuvenating the hopes of many who have resigned to fate by going back to the countryside. Erratic weather patterns, leading to poor harvests, added a toll to the welfare of the Zimbabwean rural folk who were thrown into vicious circles of absolute poverty and deprivation. Effects of climate change and the subsequent lack of productive activities became push factors in the countryside. Seeking shelter from the urban areas which seem to be now lucrative as a result of dollarization became the respond mechanism adopted by many.

Apart from that, many immigrants who have crossed borders, mostly to South Africa and Botswana, in search of green pastures as the nation was caught into a seemingly inescapable conundrum of poverty emigrated hoping to enjoy the benefits of a rejuvenating economy. This researcher contends that during the era of dollarization in Zimbabwe, nearby countries where most Zimbabweans used to flock to have become unfriendly environments which can only be relied upon for cross-border trade as opposed to permanent residence, which is at par with Dube's (2011) findings that nearby countries recently offer lucrative reserves for woman migrant traders. Memories of xenophobia were still fresh in the minds of Zimbabweans in South Africa when the multicurrency system was adopted. This necessitated immigration by individuals hoping to make a better life at home, especially those with unutilised professional skills. In a situation where it was difficult for those who have left jobs especially in the public service to be reengaged, informal vending became the livelihood option for many due to its ease of entry as also noted by Dube and Chirisa (2012). As noted earlier, the rural areas have lost glamour due to lack of productive activities stemming from low rainfall as well as the effects of climate change. Thus, Masvingourban

was massively invaded by citizens flocking from the rural areas and nearby countries. At the same time, those in formal employment were subjected to meagre earnings not commensurate with the costs of living. This means that even school children could reconcile work and school to sustain a living in the easily accessible and most flexible informal sector (Gukurume and Nyanga, 2011).This is enough evidence to support the claim that dollarization of the economy led to an exponential hike in the informal sector.

It isdeplorable to note that the city of Masvingo has been turned into a large pool of unemployed masses in the recent epoch than everbefore. Against this backdrop, the costs of living especially rentals have never remained constant at any given time. It was noted in this study that costs of rentals, school fees, rates, food, among other basic necessities rise at unprecedented levels to an extent that even the formally employed cannot support their families. One respondent vehemently stated that, "*vanhuvakajairiraZim dollar raikwidzwamitengo everyday uye US dollar rakauyavanhuvachangobvamukuburnersakavavekungoburnermitengokutivawanemariyakawanda"* (people are used to the Zimbabwean dollar era where prices changed on daily basis and the US dollar came while people had just left the practise of money burning prompting them to burn prices to gain more money). The resultant inadequacy of salaries propel even the formally employed to hire people to work for them as informal vendors or to make their children participate in the saidpractice. These established dispositions and learned habits, called habitus in Bourdieu's terms, are very crucial in circumventing the problems faced by urbanites in Masvingo urban. The entrance of the formally employed in the informal sector is not unique to this period alone, but what makes it interesting at this point in time is the pressure it adds to the already groaning informal sector. In essence, the dollarization of the economy has led to a massive expansion of the informal sector.

THE EFFICACY OF SOCIAL CAPITAL IN SUSTAINING THE VENDOR ECONOMY

Social capital is a valuable resource to informal vendors in Masvingo urban both to access goods and ideas as well as to circumvent the challenges faced by the vendors. This research contends that social capital is used in a barrage of ways to sustain the informal vendor economy in Masvingo urban. The massive expansion of the informal sector creates competition for vending products triggering participants in the trade to use ingenuity to create novel ways of accessing commodities for resell. It is now the norm of informal vendors to establish networks with suppliers and other informal vendors so as to access good quality products which are also scarce in the market. Vendors dealing with fruit and vegetables wake up early in the morning to do their purchases before they engage in any household chores. Not all people can manage this so some end up establishing

networks with suppliers so as to make them set their products aside. Some vendors have established a habit of befriending those with relatives who supply commodities, while others will even make their relatives bring them commodities like grain from the rural areas. While such ways are not totally new in the procurement of commodities for resell, the form it has assumed in this dollarized Zimbabwe is so pronounced. One lady stated that,

"kana ukashayawekuziva kana kumusikakwachounobvawakabatamaokokusiyakwekungeuchitogonakurikufumo-batajongwemuromo"

(if you do not know someone you may even come from the market place empty handed unless if you can wake up early morning). As demand increases, good quality products become scanty at the market corroding the effectiveness of informal vending in sustaining vendors' livelihoods. The rising demand for vending commodities which has become a novel challenge to informal vendors in Masvingo urban therefore requires social networking if participants are to sustain their livelihoods using the trade. Informal trade, which can be here equated to Bourdieu's notion of field, has therefore become an arena of struggle for survival where social capital is the most known strategy manipulated for livelihood sustenance. Informal vendors in this study emerged as very agentic and rational in responding to the challenge of scarcity of good quality vending commodities on the market.

Social capital is also instrumental in accessing the most desirable aspect in the field in question, that is, customers. The swelling of the informal sector has inevitably posed a threat of competition for customers to actors in the field. Most informal vendors who participated in the study lamented the shrinking of revenue as competition increases. Compounding thealready volatilesituation is the fact that the *chitimela*market place is accessible to all customers even those who do notbuy for resell. This reduces revenue earnings of informal vendors as demand falls drastically. It follows that actors in the informal sector, specifically informal vending, show their knowledgeability by crafting new mechanisms to ensure that they stay above their situations. While it has become a habit of many to scramble for customers, trying to lure them to buy from certain individuals, networking is the most effective way of ensuring that one maintains a good customer base. One participant noted that, "*nekuwandakwatakaitakudaimunhuangangokutengerakutiwapainternyoka here? Munhuanototengawokumunhuwaanoziva*" (considering the bulk of vendors, a customer prefers to buy from someone known to the customer). Other vendors stressed that they now have popular customers whom they give goods on credit to collect the money by the end of the month. This is usually done by those specialising in clothing and clothing materials, hair dressing materials,

blankets, among many other related materials of higher value. Thus, social capital is at the heart of the sustenance of informal vending in a competitive environment where the number of vendors seems to exceed the number of potential buyers.The role of social capital to the welfare of informal vendors even goes to ideas pertaining to business. This study evidenced the lack of associations of vendors as well as synergies required for the impartation of business skills. New comers in the sector therefore appeal to those who are conversant with the trade so as to be given information on where products are bought, how to create a big capital base, storage, among many others. This is at par with Dube's (2011) notion that most women cross border traders resort to social networking as a way of learning the germane business etiquette in situations where Bourdieu's cultural and social capitals become very invaluable in determining business nodes. The old ways of doing business are therefore utilised, a clear indication that informal vendors use their set of dispositions created and reformulated through their personal history. Cross border vendors rely on those who have a long history of vending, especially relatives, for acculturation to ensure that they escape Zimbabwe Revenue Authority (ZIMRA) duty charges. This goes hand in hand with Dube's (2011) notion that some would-be cross border traders have opted to 'acculturate' to the art of cross-border trade through skills acquired from close relatives. This is usually done through good choice of transporters who can bribe ZIMRA officials. Once one escapes duty charges, chances of having a big profit margin are high. Those specialising in meat rely on networking to get well required ideas on packaging. A vendor selling chicken cuts has this to say, "*Unless someone teaches you good packaging skills, you may sell the whole box for a loss.*" This indicates the prevalence of mutual acquaintances as major ways of training new comers. No formal training is undergone for one to join the informal sector making social capital more valuable in informally training the novice. For new comers in the trade, social capital is the basis for knowing where products are bought. Thus it requires a well serviced network for one to acclimatise with the new trade, as also noted by Muzvidziwa (1998) (17) who postulated that cross-border traders in Masvingo manipulated social networks to acclimatise with foreign lands. The sustainability of the network determines how one is to excel in informal vending. This researcher, however, shares similar sentiments with Dube (2011) that such a snowball type of business networking has had varying degrees of success. Having realised that, it suffices to note that no one can underestimate the value of networking in the sustenance of informal vending in the dollarized Zimbabwe.

THE LEGAL AND REGULATORY FRAMEWORK AFFECTING INFORMAL VENDORS IN MASVINGO URBAN

Informal vendors are still considered shoddy dealers in Zimbabwe's legal framework (Dube, 2011). The informal sector is known by a plethora of names like the 'underground economy', 'black market', 'informal economy', among many others. Such names sow the seeds of notorious upheavals faced by informal vendors as they thrive to emancipate their families from abject poverty. The catastrophes marring their trade as a result of the domineering influence of draconian laws include rounds, brutal harassment and mass arrests by municipal police and ZRP. When caught, informal vendors are fined and the whole lot of products for resell confiscated. Such regulatory and policy environment is inimical to the effectiveness of informal vending in sustaining the livelihoods of urbanites in Masvingo urban. Vendors are thrown into vicious circles of woes as they run away for dear life all day long, some winning and some losing in such endeavours. The increase in the number of officers deployed in response to the swelling number of vendors has now become a cauldron of agitation as vendors become more alert to police rather than customers in a situation where the street has been turned into a battle field where all the ruthless battles against the informal vendor economy are fought.

Despite all the harsh ways used to regulate informal vending, the sector continues to boom. At no point has the number of informal vendors decrease because of arrests. The vendors are driven by the saying '*pane mupurisandopanemari'* meaning that 'money is found where the police is.' This statement adopted from the 'blood diamonds' in Chiadzwa is now used as an invigorating tool to ensure that informal vendors do not yield to the imposing influence of the police. Thus, despite the structural constraints inimical to the development of a sustainable livelihood, informal vendors always employ strategies to sustain their livelihoods. At times the police are deployed in civilian clothing to disguise the vendors as they will act like customers who want to buy. However, vendors are agentic and rationale since they are well able to identify them. In most cases they mock such detectives by the names *'jira'* referring to an officer in civic clothes, '*ngonjo*' meaning a police officer or *'ndinindamubata'* denoting a neighbourhood, alerting each other to flee. As noted by Dube and Chirisa (2012), in recent times, the informal sector in Zimbabwe has worn a new face as the actors have designed new adaptive strategies to counteract restrictions and evictions and by-laws imposed on them. This researcher also shares similar sentiments with the aforementioned authors that the urban informal sector comprises multifarious activities and actors in it have a tool kit of strategies they employ to defend and be resilient in their livelihoods. Informal vendors are

therefore cognitive beings who can use ingenuity to circumvent the problems they face in their daily lives.

As the coercion of police continues to threaten the activity of informal vending, vendors manipulate social capital to ensure their continued existence in the streets. Bribery of police officials, known by the native Shona term '*kudusa*' in Masvingo urban' is now rampant. This is supported by evidence from a participant who postulated that "*kana zvakasungaunotodusa*" meaning "when the situation is tense you pay." When asked on the impediments of policy effectiveness, a council official responded: "*bribery is the cancer bedevilling the effectiveness of our policies."* Bribery is not only done in the field where street vending is carried out. Cross border traders use the same mechanism to ensure that they escape duty when they cross borders especially South Africa back to Zimbabwe. ZIMRA officials have the prerogative of ensuring that the nation gains some revenue from those who import goods for resell. However, the fulfilment of the mandate is thwarted by the gullibility of some kleptomaniac officials at border posts who display their eagerness to gain at the expense of the nation to let informal vendors import their goods duty free. Clear from this adaptation by the informal players is that the sector cannot be eradicated in its entirety (Dube and Chirisa, 2012). It follows that social capital is the fundamental base for the sustenance of the informal sector in general and informal vending in particular. In a situation where the informality tag continues to haunt the welfare of informal vendors (Dube, 2011), most successful vendors require social capital to make the ends meet. This is enough testimony to the fact that despite being invisible to the attention of many researchers, social capital plays a prominent role in an era where every actor tries to retain every cent earned for the sustenance of livelihoods. This research accentuates that social capital is useful in transcending the negative ramifications of the legal and regulatory framework marring the welfare of informal vendors in Masvingo urban.

This research has also contributed immensely to the realisation that despite the council's relentless efforts to cast the informal sector into oblivion by introducing formal markets in the form of the *chitimela* market place as well as a clothing market place opposite Mucheke bus terminus, informal vending continued to establish rhizomes in the city. As the municipality and police quicken efforts to extinguish informality, some vendors resort to what Dube and Chirisa (2012) calls nocturnal vending by operating during the night when predator (police) would have dismissed from work. Some have established habits of coming to the streets after work as they ensure that their formal jobs are complemented by informality. Hives of activities from around 1600 hours to around 2200 hours were realised in Chesvingo drive, a street stretching from Chesvingo business centre (township) popularly known as Sisk to Chiwororo business centre popularly known as Pangolin.

Most participants rendered this road the busiest road in Masvingo both during the day as well as the night to the extent of joking that anyone who doesn't know the road doesn't know Masvingo. Nocturnal vending is a useful strategy used to override the regulatory framework. This means that instead of persisting with the demonization of the vendors in question on the account of the informality label, new policies need to be put in place to ensure that the sector is integrated into the larger economy. This research advances that unless and until policies towards informal vendors change for their inclusion into the broad array of formal activities, the city of Masvingo will continue to lament untold suffering as a result of informality. More energy and resources will continue to be released towards efforts to bring the informal sector in general and informal vending in particular to a halt, but as have been witnessed hitherto such efforts shall remain relentless since even the bulldozer of the operation clean up campaign or Murambatsvina has failed to remove the informal vendor from the street (Association of African Planning Schools, 2012) (18). Informal vendors have remained agentic in responding to the threats emerging from the police. Policy makers, academics and the government must therefore combine efforts to ensure that the informal sector is incorporated into the wider economy so as to ensure that the nation enjoys the proceeds from the sector.

Narratives from ZRP and municipal police officials indicated that the crackdown on informal vendors is a legal endeavour which is not peculiar to the era of dollarization alone. It was indicated that even prior to Operation Murambatsvina of 2005, illegal vending was punishable by law. Although municipal authorities acknowledge that there is need for the education of vendors on the by-laws they must comply with, it was also clearly stated that most vendor are aware of the municipal by-laws on vending especially stipulations on vending sites and vending licences. Most areas where informal vending is done are not permissible prompting the responsible authorities to apply the law where it must be applied. It emerged from this study that while vending is of economic benefit to the vendors, given high unemployment levels in Zimbabwe, vendors also pose other challenges like pollution in cities, especially in areas not designated for vending. However, the council indicated that vending space in the city was also an issue of concern since all designated sites were flooded with vendors. This means that illegal vending in the city is also promoted by the failure of the municipality to provide vending sites commensurate with the rising demand for vending licences. This researcher unearthed that scores of applicants were put on waiting list to have vendors' licences but vending space is the major problem inimical to the development of a formal vending sector. However, it was also established that availability of vending space alone cannot bring informal vending to an end since even those with vending licences engage in informality especially through selling unstipulated products at legal vending sites.

THE DEMONIZATION OF INFORMAL VENDING AND THE PROSPECTS FOR RECOGNITION

The informal sector has continued to boost an imperfect track record in Zimbabwe despite its value in sustaining the country's economy since the year 2000 when the formal economy failed to provide employment and revenue base for the majority of unemployed Zimbabwean masses (Dube: 2011). It is more apparent that the same sector is still playing an instrumental role in sustaining the livelihoods of the nation in a country where the salary of the average person is less than half the poverty datum line. As Dube (2011) noted in his study of woman cross border traders in Zimbabwe, an informality tag is placed on street vending as informal vendors are considered clandestine and shoddy dealers. This study established that informal vendors are considered criminals who are supposed to face the same brutal treatment as thieves and sex workers, the only difference being the sentence. Transpiring in Masvingo urban is a situation where the geographical city is given more value than human life as indicated by the demonization of informal trade which is considered a public nuisance. Notions of urban cleanliness are always attached to massive arrests of informal vendors on accusation of pollution while at the same time they are blamed for propagating criminal activities like thieving. Informal vendors have become the easiest target for ZRP and municipal police while the real criminals are let go. It is therefore the contention of this research that the demonization of informal vending must not go without careful scrutiny if the value of informal vending to the larger economy is to be comprehended.

The informality label placed on informal vending carries with it negative ramifications as far as the recognition of informal vendors is concerned. The government continues to pay a blind eye to the needs of informal vendors. Education and empowerment has remained a far cry to informal vendors. Even the ministry of Small and Medium Enterprises (SMEs) shows no enthusiasm to incorporate informal vendors into its core business and to assist them with the necessary information required for popular participation in national development. Instead, the ministry is concerned with registered small enterprises as if they are the only ones responsible for sustainable development. The civil society has at no point shown concern for the challenges faced by informal vendors in Masvingo urban, let alone lobby for their integration into the larger economy. Hopes of recognition for the informal sector therefore become fallacial imaginations which abruptly varnish with the brutality inflicted on participants in the sector. Lack of synergies has remained a major problem impinging on the welfare of the informal sector as the voices of informal vendors remain unheard. Considering that most households' livelihoods are inextricably inseparable from the informal sector, the demonization of the informal sector has huge implications to development in

general and sustainable development in particular. This research therefore stresses the need to fully recognise the value of the informal sector and integrate it into the larger economy to make sustainable development a reality. Empowerment of the grassroots is in most cases the panacea to sustainable development.

Despite their lack recognition, informal vendors continue to thrive for survival. To most vendors, social capital becomes the only way to circumvent the problems of lack of association and representation. Bourdieu's cultural and social capitals become very invaluable in determining business nodes (Dube, 2011). As noted earlier in this study social capital is the fundamental base on which the impartation of business skills in the informal sector is laid. The rule of thumb is used by most informal vendors who manipulate their habitus (historically established habits of doing things) to transcend the turning points they are thrown in as a result of lack of synergies in the field of informal trade. This concurs with Dube's (2011) notion that most women cross-border traders resort to social networking as a way of learning the germane business etiquette. It was however noted that measuring the level of effectiveness of learning business that way is always difficult. This calls for the placement of newer policies on informal vending, giving specific stakeholders the obligation to fully educate and empower informal vendors.

CONCLUSION

The dollarization of the Zimbabwean economy has led to an exponential hike in the number of informal vendors in Masvingo urban. Despite the booming of the sector and its role in sustaining the lives of many households, informal vending has not been given sufficient positive audience in Masvingo urban. Lack of synergies and associations remains a daily reality marring the welfare of informal vendors. The legal and regulatory framework on informal vending has remained unfavourable as most informal vendors lament their subjection to brutal treatment at the hands of ZRP and municipal police. The demonization of informal vending and the informality label associated with the practice still haunts the effectiveness of the livelihood strategy. In spite of the daily catastrophes bedevilling the informal sector, informal vendors have remained resilient and resort to ingenuity to sustain their livelihoods. Social capital is manipulated for the acquisition of relevant skills in the sector, acclimatisation with foreign environments as well as circumventing the challenges of duty payment on border posts as well as arrest by police in the streets. However, the effectiveness of such mechanisms in rescuing the city from the snare of abject poverty is sometimes questionable.

RECOMMENDATIONS

This study contends that unless and until the informal sector is integrated into the wider economy through creating valuable synergies so as to empower informal vendors, the nation will continue to be wallowed in absolute poverty. As such, the government and civil society do have the mandate of promoting the sector which is sustaining the livelihoods of many Zimbabweans by ensuring popular participation of the actors concerned in national development. Policy makers should find ways to embrace and incorporate informal vending as it is the largest employer in Sub-Sahara African cities (Association of African Planning Schools, 2012). Legal recognition of the informal sector is crucial if the gains of informal vending are to translate to national development. Policy makers, academics and the government must combine efforts to ensure that informal vendors are educated and empowered to ensure that the nation enjoys the proceeds from the informal sector. It is also recommended that the municipality create more vending sites to respond to growing demand to reduce informality in the city. The ministry of SMEs should be given the mandate to empower informal vendors by imparting them all the necessary requirements for them to join the formal sector.

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An Investigation into the Causes and Effects of Spouse Abuse: A Case Study in Nyanga Urban In Manicaland Province, Zimbabwe.

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ABSTRACT

Spousal relationship is the backbone of any development in any community. A healthy marriage relationship nurtures harmony, unity and healthy community life style. The present study investigated the causes and effects of spouse abuse in Nyanga Urban in Manicaland province, Zimbabwe. Spouse abuse in Nyanga Urban has resulted in broken marriages, child suffering, suicidal cases and unhealthy community relations, which subsequently inhibit development.

During the period of the study, Nyanga Urban had a population of 2,500. Stratified sampling was used to obtain a sample size of 200 respondents (100 males &100 females) aged between 19 to 65 years. A mixed methodology (quantitative –qualitative) approach was used. In Phase 1 of the study a questionnaire with closed and open-ended items was used to obtain quantitative and qualitative data. Data yielded by the survey provided an overall picture of spousal abuse in Nyanga Urban. Phase 2 obtained in-depth understanding of spouse abuse through and in-depth interviews and focus group discussions which produced rich qualitative data. Qualitative and quantitative data analysis techniques were used for organizing, analyzing, presenting and discussing the findings.

The research revealed that spouse abuse occurred due to infidelity, ineffective communication styles, cultural practices such as appeasing evil spirits, and alcohol abuse. Spouse abuse results in psychological, emotional and social problems among the spouses subjected to abuse as well as those close to them.

Two key recommendations from this study are: First, there is need to revisit some of the cultural practices which tend to promote gender inequality within families. Second, institutions such as churches should continuously conduct family sessions to equip families with skills to handle issues of spouse abuse so that development is not adversely affected.

Key Words: spouse abuse, community, marriages, focus group.

INTRODUCTION

Spouse abuse has a history which dates back from the Roman Empire where males had legal rights to discipline or even to kill their wives even for minor misbehaviour (Chelfant and Labeff, 1988). The world over, issues of gender disparities have created wide gaps between males and females even within some marriage relationships. The increase of gender inequalities, cultural practices, negative attitudes and behaviours in the families seem to have initiated a lot of suffering thereby fuelling negativity in production from family to global levels. Because of the development of poor relationships within families, many cases of abuse arise some of which are known and reported while some are swept under the carpets (Taylor and Stewart, 1991).

Dobash and Dobash (1979) in Chelfant and Labeff (1988) argue that women are seen as appropriate victims because violence towards them is common and it is viewed with tolerance not only in history but even today. For example, a research carried out by Strauss, Gelles and Stein in America in I978 revealed that close to two million wives were beaten up by their husbands each year for various reasons including infidelity, barrenness and finance. While abuse of women can be common in some research, it is also true that men are also victims of such abuse. For example, research findings of 1980 by Strauss, Gelles and Steinmetz in America revealed that two million husbands were attacked by their wives each year for draining family finances in unnecessary activities. This implies that both spouses are victims of abuse only that at times some of the cases are not reported for cultural reasons.

From the Zimbabwean point of view, some evidence of spouse abuse can be drawn. The Herald of 2 March 2007 published an article of a twenty –three (23) year old woman who hacked her husband to death with a hoe because he had married another wife. The Catholic News Magazine Number 27 0f August 1996 quoted an article from The Mirror in which a husband assaulted his wife to death using a vehicle fan belt. In another sad incident, The Zimbabwe Herald of 17 March 2010 published a story of a husband who short his wife to death with a gun and later killed self for infidelity. In Makoni village in Zimbabwe, the Globen number 44(2007) Magazine also published a story in which a drunken man used to beat his wife in the presence of their children. Given this background, it is clear that the world has a lot to tell about spouse abuse. Spouse abuse negatively affects the family and the community because it promotes unhealthy and dysfunctional family life-style. The desire for any kind of positive development is inhibited.

Efforts to stop spouse abuse have been made by the government of Zimbabwe. For example, sixteen days of activism against gender-based violence were launched in November 2006 under the theme, “Changing attitudes, practices and behaviours that promote gender-based violence. ‘ Non-

Governmental Organization such as Family Aids Caring Trust has introduced programmes that aim to encourage behaviour change within families so as to have a healthy and productive nation.

Musicians as well, have made some significant attempts to make communities aware of the evils of spouse abuse. For example, Oliver Mutukudzi's song, '*Tozeza baba*," **We are afraid of father**, has this to say about spouse abuse:

> 'Father your beating of mother is too much
> *"Imi baba manyanyakurovamai"*
> Your scolding of mother is too much "
> *"Imi baba manyanyakutukamai"*
> How can we children be happy?
> *"Motiisuvanatofarasei?"*

Furthermore, in 1985, the Zimbabwe government passed the Domestic Violence Act (Chapter 5:16) as a provision for the protection and relief of victims of domestic violence. Gender-based movements such as Gender and Development, The Musasa Project, Padare and many others were established in order to educate and empower the Zimbabwean community to appreciate peace, equality and positive change for the welfare of humanity. Despite such positive efforts, spouse abuse is on the increase.

The causes of spouse abuse differ from one society to another because of cultural variations. In Nyanga urban, whether spouse abuse is a result of the above reasons was yet to be investigated. It was against this background that the researchers wanted to find out why spouse abuse continued to be a problem when efforts are made to encourage harmony in order to establish optimal relations within the family institutions.

STATEMENT OF THE PROBLEM

Spouse abuse in Nyanga urban has caused a lot of broken marriages and discomfort in children and society. Given this view, the researchers were interested in investigating the real causes and effects of spouse abuse in this area.

PURPOSE OF STUDY

The study was aimed at establishing the causes and effects of spouse abuse to marriage relationships and family life in Nyanga urban. The study was also aimed at rebuilding healthy families for positive community development.

OBJECTIVES OF THE STUDY

The research was conducted guided by the following objectives:

I. To find out whether the people in Nyanga urban knew what spouse abuse is.
II. To ascertain reasons for spouse abuse.
III. To assess the reactions of spouses towards the abuse.
IV. To find out the society's perceptions towards spouse abuse.
V. To assess the effects of spouse abuse on the life of the family.
VI. To identify strategies to reduce the rate of spouse abuse.

RESEARCH QUESTIONS

I. What is spouse abuse?
II. Why do spouses abuse each other?
III. How do spouses react to spouse abuse?
IV. What are the perceptions of the society towards spouse abuse?
V. How does spouse abuse affect family life?
VI. What strategies can be employed to reduce the rate of spouse abuse in Nyanga?

SIGNIFICANCE OF THE STUDY

The significance of the study explains how worthy the solutions to the problem are both theoretically and practically implemented (Best and Khan, 1989). It is hoped that:

- The research findings will encourage the Nyanga community to critically assess some cultural practices which promote spouse abuse.
- The research findings will empower the Nyanga community with knowledge and skills to handle family disputes peacefully.
- The research findings will encourage institutions and organizations to organize programmes that are aimed at promoting harmony at all community levels.
- The research findings will provide a fertile ground for further studies on the same topic.

ASSUMPTIONS OF THE STUDY

The study was based on the following assumptions:

I. Spouse abuse has various interpretations based on cultures.
I. Spouse abuse is caused by differences in opinion within families.
II. Society has mixed perceptions towards spouse abuse.

III. Spouses react differently to spouse abuse.

IV. Spouse abuse negatively affects family life.

DELIMITATIONS OF THE STUDY

Chikoko and Mhloyi (1995) define delimitations as the precise limit of the issues that the researcher is to cover. It defines the zone within which the researcher's findings can be held accountable. Nyanga urban is near the border with Mozambique, Makoni and Mutasa districts such that the community is greatly influenced by cultures from these areas. It is close to three prominent hotels and some resorts which attract tourists. There are also some Inns and lodges where people enjoy their lunches and dinners. Nyanga urban is also surrounded by timber plantations and fruit farms which also attract workers of various cultural backgrounds. Nyanga community has strong belief in its cultural practices.

LIMITATIONS OF THE STUDY

The researchers encountered the following limitations during the period of the study:

The topic was sensitive and some of the respondents were hesitant to release information for fear of victimization. The researchers assured them of confidentiality and anonymity and that the information was the for the purpose of this research only. The researchers had financial problems to travel to Nyanga but assistance was sought from colleagues. Because of the diverse cultures in this place, it was not easy to gain entry into all intended households. Multi-cultural and cross cultural approaches were employed.

THEORETICAL FRAMEWORK

The cognitive approach was used to assess the cognitive processes of the respondents (Nelson-Jones (1997). The Rational Emotive Behaviour approach was employed to promote rational behaviours, (Ellis, 1962) The Social learning Theory by Bandura (1963) was used to promote positive cognitive capabilities. The Humanistic Theories were used to encourage positive self-growth, freedom and self-concept (Nelson-Jones, 1997). Multicultural approach was used to assess and accommodate all cultures (Haralambos and Holborn, 1995). The Gender theories were also used to encourage gender mainstreaming and inclusion.

METHODOLOGY

RESEARCH DESIGN

The qualitative paradigm was employed in this study. This was appropriate because it enabled the researchers to collect in-depth information on what people say or do in their natural settings (Bogdan and Biklen, 1990). This research paradigm was quite suitable because it helped the researchers to collect in-depth information on the causes and effects of spouse abuse. The question of perceptions and attitudes is an abstract concept that requires direct inquiry so as to unravel perceptions because they lie at the heart of the respondents (Barbie, 1992). Although this approach was successfully used, the researchers experienced some difficulties because of multiplicity of perceptions. To overcome this short coming the researchers borrowed some quantitative techniques in data analysis, presentation and interpretation.

RESEARCH INSTRUMENTS, POPULATION AND SAMPLE

The researchers used interviews with guided open-ended questions, a questionnaire with open-ended questions to solicit information on the causes and effects of spouse abuse. The same questions were administered on both interviews and focused group discussions. The researchers also probed further to ascertain why spouse abuse was on the increase in Nyanga urban. The questionnaire was administered without supervision as information required was merely factual and this instrument had a wide coverage of content and contextual information on the causes and effects of spouse abuse.

From the population of two thousand (2000) people in Nyanga urban, a sample of two hundred respondents was selected using stratified random technique because the community lived in various suburbs (Borg and Gall, 1999). The sample constituted 100 men and 100 females. This sample size was deliberately selected because the researchers needed a balanced gender equity distribution of ideas from both sexes.

The data collected through the interviews and focused group discussion was carefully coded and presented descriptively. Quantitative data collected through the questionnaire was presented in forms of tables, and discussion.

DATA PRESENTATION, ANALYSIS AND DISCUSSIONS

I. WHAT IS SPOUSE ABUSE?

Spouse abuse had various interpretations as tabled below:

DEFINITION	FREQUENCY	%
An expression of love to a spouse	20	10
A sign of authority to a spouse	15	7 1/2
A barbaric behaviour on a spouse	25	12 1/2
A well planned behaviour to suppress a spouse's opinion	30	15
A cultural practice of expressing authority over a spouse	60	30
An unacceptable behaviour that you do not love your spouse	50	25
TOTAL	**200**	**100**

From the responses given above, it is clear that spouse abuse in Nyanga urban is generally a negative cultural practice which is used to exercise power and authority over a spouse. It is a culturally structured inhuman behaviour inflicted to a spouse by another spouse, (Day-Vanes, et al, 20030).Therefore, if a behaviour is backed by culture, it is sometimes not easy to remove.

WHY DO SPOUSES ABUSE EACH OTHER?

The table below shows the responses of the above question.

RESPONSES	FREQUENCY	%
Economic hardships	25	12 1/2
Un employment	20	10
Differences in opinion	40	20
Men think that they have bought the wives	30	15
When a spouse abuses substance and alcohol	25	12 1/2
Age difference through child pledging	60	30
TOTAL	**200**	**100**

The reasons for spouse abuse show that in most cases in Nyanga urban, spouses abuse each other when there is an age difference and when there is disagreement in the marriage relationship. This occurs because of the activities around this place. These include illegal border crossing to Mozambique in search of old clothes and dried fish. Also fruit and timber plantations as well as

tourism attract people from different places. Men tend to be attracted by young women who converge in this town and subsequently marry each other. It was also revealed that child pledging was common in this area. This happened because families would want to appease spirits or as payment towards some borrowed property. Sometimes two families would just appreciate each other so the elders may decide to bond the relationship through marriage. If it happens that there is no elderly female child in a family, a young girl will be forced into marriage with a man far above her age. These practices seem to be influenced by culture and environment. Therefore, when a spouse does not appreciate the opinion of another spouse, misunderstandings would occur and one is forced to comply.

One other cultural source of spouse abuse is that of lobola which men use to perpetuate abuse towards their wives. By paying lobola, wife must remain an object and depend on the husband. Should a woman try to disobey any instruction then she is silenced even when her opinion is legitimate. Therefore, lobola is used by some men to exercise their authority. Sometimes a woman fuels the issue of lobola when a husband brings an idea which she is against. She can say, "How much did you pay my parents in order to marry me? Therefore, the issue of lobola, being a cultural practice is a critical source of spouse abuse. Economic hardships and unemployment also caused spouse abuse. These two sources were said to cause stress. Sometimes a spouse drains the little resource such as money which was meant for the family, causing misunderstanding. Failure to handle the problems posed by economic hardships would result into venting out anger and frustration directed to each other in a marriage relationship (Rush, 1990).

Low income can also strain on the marital relationship especially in urban settings where there is competition (The Musasa Project, 1996). Sometimes when the husband is not employed and the wife is employed, it is not easy for the husband to ask for some money from the wife. Therefore, he feels inferior yet he needs to show his father- hood. He therefore demands a share from the wife and when the wife refuses, quarrels erupt, thereby causing abuse. The above reasons were said to be some of the causes of infidelity within marriage relationships. When there is no love in marriage, spouses are likely to satisfy their sexual desires outside marriage (Kanyowa, 2003). This caused contraction of HIV and AIDS. Furthermore, children born by abusive parents tend to be neurotic and become a problem in the society (Gandari et al, 2010). This subsequently impact production from family to community levels.

II. REACTIONS OF SPOUSES TO SPOUSE ABUSE: HUSBANDS' REACTIONS

VARIABLES	MALES	%	FEMALES	%	TOTAL	%
Keeping quiet	70	35	40	20	110	55
Walking away	20	10	50	25	70	35
Fighting back	10	5	10	5	20	10
TOTAL	**100**	**50**	**100**	**50**	**200**	**100**

The responses given indicated that usually husbands tended to ignore when abused. This makes them suffer in silence. However, such behaviour by men would not mean that they are not pained by abuse. In fact, some men would even fear their wives and they kept quiet. This is would be a sign of surrendering their authority to the wife. This makes them safe. Sometimes husbands lock themselves up in bedrooms and keep quiet while some would simply seek refuge away from the abusive wife. Culturally, men do not show that they are pained. They naturally strong so they just walk away, this is why such cases are not reported (Gelles and Cornell, 1985).In some complementary marriage relationships, the husband retaliates so as to demonstrate his supremacy. However, such behaviour tends to fuel more anger on the abuser and finds dangerous objects to keep on abusing the husband.

Such behaviours within marriage relationship might have been learned from the environment or it is from one's background. However, whichever way it is, the issue of human rights is sometimes violated within marriages causing a lot of discomfort not only to the family members, but to the community as well .(Taylor and Stewart, 1991).

III. REACTIONS BY WIVES ON ABUSE

VARIABLES	MALE	%	FEMALE	%	TOTAL	%
Using aphrodisiacs	80	40	60	30	140	70
Pouring hot liquid	15	7 ½	37	18 1/2	52	26
Keeping quiet	5	2 ½	3	1 1/2	8	4
TOTAL	**100**	**50**	**100**	**50**	**200**	**100**

Women reacted by using a common practice of aphrodisiacs. This is a cultural practice to make the husband very soft and obey instructions without any word of murmur. The use of aphrodisiacs is common in Nyanga as reported by the interviewees. It is used even when there is no abuse so as strengthen the degree of love and obedience. In the case of abusive husband aphrodisiacs make him

submissive to the wife. From the cognitive point, the practice is irrational because it makes a person develop behaviours which may be unacceptable in the society. Some men become so quiet and submissive that they are always close to their wives even at some funerals. People then begin to wonder what has happened. This becomes a violation of human rights (Mwamwenda, 1995).

Using hot liquid or any object to retaliate to the abuse was also a common practice of reaction by women. In fact, this is done when the man is unaware. Common liquids used were boiling water and very hot cooking oil. These substances are very dangerous because they damage the skin causing permanent scars. When this happens, the victim is reminded of the abuser thereby causing some trauma and pain (Oosthuzena and Piet, 1992). Some wives would be quiet to the abuse as a sign of being obedient and submissive to their husbands. From the discussions held, it was stated that such women were from Christian families and would favour dialogue to settle their affairs. Therefore, communication becomes the key to such issues (Van Pelt, 2008).

IV. SOCIETY'S PERCEPTIONS TOWARDS SPOUSE ABUSE

The negative perceptions of the society towards spouse abuse were an indication that the society was affected by such behaviours. The rate of spouse abuse is a threat to the Nyanga community because it causes a lot of suffering to the nuclear and extended family members. This weakens children's vulnerability contexts. Perhaps the negative perceptions are a result of cross and multi-cultural influences in which communities emulate from each other. However, because of the influence of religions such as Christianity and Hinduism that have gained some ground, the community has developed some positive behaviour change towards spouse abuse. According to the statistics analysis, there is very little difference of 20 (10%) between the two variables. This may suggest that there is still a gap and more strategies are needed to educate and empower the community on their rights and to appreciate gender equity (Kabeer, 1996).

EFFECTS OF SPOUSE ABUSE ON THE FAMILY

SOCIAL EFFECTS

Research findings reflects that 80 (40%) of the respondents indicated that a family which is characterized by spouse abuse developed poor family relationship. 40 (20%) of the respondents stated that children born of abusive parents also become abusive. 35 (17 ½% of the respondents said that production and socialization are inhibited when spouses abuse each other. 25(12 ½% of the respondents indicated that children become victims of labelling by others in the community while 20 (10%) stated that relatives are disturbed by spouse abuse of their family members. According to

Kanyowa (2003) when a family experiences spouse abuse it becomes dysfunctional and unhealthy. In most cases children with such backgrounds become bully and violent in the society. They develop irrational behaviours (Chelfant and Labeff, 1998). From a theoretical perspective the children from such background fail to model good behaviour and to make appropriate decisions (Beck and Ellis, 1997). When these children also marry they treat their spouses in the same manner hence, neurosis. They become a serious problem and a social outcast in the community.

PSYCHOLOGICAL EFFECTS OF SPOUSE ABUSE.

According to the responses given, spouses who experienced abuse developed some fears which had 50 (25%) responses. Feelings of guilt, burn- out and low self-esteem effects had 40 (20%) responses and suicidal tendencies had 30(15%) responses. From a qualitative perspective, a human mind should not be overloaded with such issues because it is tantamount to severe health problems (Haralambos and Holborn, 1995). Overwhelmed with problems, the mental power is reduced, guilt consciences, anxieties, burn out and self-unworthy develop. Subsequently, one will decide to divorce or commit suicide; therefore spouse abuse should be avoided.

EMOTIONAL EFFECTS OF SPOUSE ABUSE.

Research findings showed that 60(30%) of the respondents said high tension develop when a spouse is abused by a spouse. Stress and burn- out had 50(25%) of the total respondents while 40(20%) said that sadness and self-isolation are also serious effects of spouse abuse. The emotional characteristics discussed above suggest the degree to which spouse abuse affects the human mind especially children. According to Van Pelt (2008) whenever the mind is compounded with such issues, the person is most likely to develop unfriendly behaviours to the environment. Chiremba and Makore/Rukuni (2007) also argue that stress and burn- out may result in a person committing suicide. Therefore, emotions that arise as a result of spouse abuse damage one's life and should be avoided.

From a health point of view, spouse abuse creates a fertile ground for mental discomfort in the family. On children, it causes feelings of guilt and shame, helplessness and hopelessness and they may decide to live in the streets. On the victimized spouse, it causes lack of interest for social commitment. Love and sex desires fade, while misery and anguish dominate (Kanyowa, 2003, Taylor and Stewart, 1991). The home becomes a place of torture and divorce becomes inevitable.

CONCLUSIONS

The findings of this study revealed strong evidence of spouse in Nyanga urban. Culture was the most influential tool that promoted spouse abuse. Child pledging, age differences in marriages,

socialization process and the disregard of a spouse's opinion dominated as causes of spouse abuse in Nyanga urban. Unemployment, alcohol and substance abuse and economic hardships were also mentioned as causes of spouse abuse. Because of its geographical status and strategic position, Nyanga urban is a multi-cultural place. Therefore, the interpretation of spouse abuse received mixed versions. The general understanding is that culture shapes the way society perceives issues. In the study spouse abuse was a culturally structured practice of suppressing a weaker spouse. However, to some cultures, spouse abuse is a private affair which no one should interfere with, therefore, the cases are not reported and the victims continue to suffer. To some extent, however, some spouses may feel that their rights are violated and they treat this as an abuse. For example, in a marriage relationship a husband would want to have sex. In the African culture, the issue of negotiation is invalid and the wife may feel irritated by such behaviour. To her this is abuse, yet our culture is important.

The mixed interpretations of spouse abuse from the respondents also suggested that the community in Nyanga urban perceived spouse abuse as either positive or negative. Negative attitudes towards spouse abuse were an indication that it is learned to abuse a spouse. From the cognitive school of thought, behaviour that is learned can also be unlearned (Sprinthall and Sprinthall, 1981). If therefore, the community receives more education and information on human rights and gender equality, more positive perceptions on spouse abuse will be achieved. The research findings revealed that spouses react differently when they abuse each other. When husbands are abused by their wives, they pretend as if nothing has happened. This may imply that some men are able to realize that if they fight back or respond to the abuse, this may fuel the emotions of their wives. In fact, it becomes humiliating if the two exchange bitter and painful words in the presence of their children. However, men's behaviour does not solve any problem because solutions are usually through dialogue. Therefore, if this has not been resolved the problem still remains as it was, thereby causing more harm to the family. This is why perhaps many of the cases of abuse on men are not reported.

Wives' reactions to men's abuse revealed that some are heartless because the use of hot liquid as a means of fighting back is just as good as killing by intend. They do not know the repercussions of such behaviour, particularly when the man is hospitalized, care and resources are needed. On the other end, some women would keep quiet and use some aphrodisiacs with a belief of making the husband lose his authority over her and the children. This is painful because some men would even be so soft to the extent of confining themselves around the home and never to associate with the outer environment.

In some cases women accepted the abuse on cultural belief that the abuse is normal and it is an indication of strengthening the relationship (Chalfont and Labeff, 1988). Even when the abuse becomes routine, the wife deceives herself that it would be the last time because the husband apologies and showers her with presents after the abuse. In some cases as well, abused women endure abuse because of the love for their children and they may be also old to start a new family hence, Steve Makoni's song, "*Handiende, ndinogariravanavangu; ndinofiravanavangu.*"

I will not go I will stay for my children's sake; I will die for my children.

The above findings are pointer to the fact that spouse abuse seriously causes unhealthy life-style within family life. In fact the nuclear family is the source of the community. It also represents a community. If this source is unhealthy, then the community also becomes unhealthy. In fact, from a sociological perspective, the concepts of "ubuntu" and "collectivism" are very important. Ubuntu means humanity, which means "I am because you are". If therefore, "I am not" it also means "you are not". As a subsystem of the community, nuclear families should demonstrate love and respect of each other. When love and respect fail, dishonesty and mistrust prevail, leading to some intimacy outside marriage (Van Pelt, 2008).

Because parents are always in disputes, children become misfits and dull in school or they do not even go to school. Usually they become vulnerable. Life of misery becomes the order of the day. This is very unhealthy. It is clear from the findings that the issue of gender inequity at family levels is a common and thorny issue in Nyanga urban. This is enhanced by culture. It is therefore, important to assist the community with programmes that aim at encouraging behaviour change.

RECOMMENDATIONS

The following were the recommendations made in order to promote healthy families:

- There is need to launch education and awareness campaigns which target school children so that they are aware of their rights with regards to cultural beliefs and gender issues which are used to oppress them by the society.
- There is need for some institutions to establish trained counsellors who assist in empowering spouses with decision making skills and encouraging early reporting of spouse abuse cases.
- Churches should conduct pre-marriage counselling sessions to encourage and prepare healthy future marriage relationship.

- Community leaders should be encouraged to revisit some cultural beliefs which tend to perpetuate gender inequality and gender oppression.
- There is need to set stiffer penalties against perpetrators of spouse abuse so that they feel the painful effects of violating human rights.
- There is need to change people's mind set to appreciate and conform to the changing world of peace, harmony and love.
- Out-reach programmes that are aimed at educating the rural communities on the Domestic Violence Act need to be organized. This is because rural communities tend to be neglected on important programmes that promote people's welfare.
- Boys and girls should be afforded equal educational opportunities to lessen the rate of illiteracy which tends to bar some individuals from exposure to some valuable media and environment.
- Gender- based advocacy programmes should be encouraged to promote open communication and discourage the use of violence to solve domestic issues.
- There is need to Africanize the Counselling profession in order to accommodate cultural knowledge, skills and competencies that can be of use in solving family issues.
- There is need for further research to open more opportunities that realize new facts on the causes and effects spouse abuse.

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APPENDIX 1

A QUESTIONNAIRE FOR ALL PARTICIPANTS

INSTRUCTION

Please answer all questions in Section **A** and **B** honestly. Information gathered through this questionnaire will be treated with strict confidentiality. Use an (X) in the space to indicate your response.

1.0 SECTION A

1.1What is your sex? Male------ Female

1.2 What is your age group?

16---19 20---30

31---40 41—50

50+ ----

1.3What is your marital status?

Married------ single -------

Widow /er---- divorcee----

1.4 What is your highest level of education?

Primary------- Ordinary level---------

Form 2-------- 'A 'level---------

2 SECTION B

2.4 In your own words define" Spouse Abuse"----------

2.5 For question 2, rank the variables from highest (1) to lowest (6)

VARIABLES	**RANK**
Economic hardships	
Un employment	
Differences in opinion	
Men think that they bought the wives	
When a spouse abuses substance and alcohol	
Age difference through child pledging	

For questions 3 &4 rank the variables 1 to 3 (highest to lowest).

2.3. How do Spouses react to spouse abuse?

VARIABLES	RANK
3. HUSBANDS' REACTIONS	
Walking away	
Keeping quiet	
Fighting back	
4. WIVES' REACTIONS	
Using aphrodisiacs	
Pouring hot liquid	
Keeping quiet	

5. How does society perceive spouse abuse? Justify your response.

Negatively --------- **Positively----------**

---

6. How does spouse abuse affect the family life?. Use the variables below to state the effects.

VARIABLES **EFFECTS**

Psychological ----------

Social ----------

Emotional ----------

Any other ----------

7. State any three strategies which you think can be employed to reduce/ stop spouse abuse in Nyanga urban.

An Investigation into the Causes of Fraud in Banks in Zimbabwe

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Abstract

The research study investigated the causes of fraud within banks in Zimbabwe. The research adopted the descriptive survey research design. Purposive Sampling technique was used to select respondents. Primary data was collected using questionnaires and interviews. The major findings of the research were that banks internal controls in Zimbabwe are weak. It was also found that staff motivation was low and bank employees had not gone under any fraud related training. The research recommended that banks need to tighten internal controls, improve employee motivation, and send their employees for fraud prevention training.

Key Words: fraud, banks, internal controls, fraudulent, capital markets.

INTRODUCTION

Banking fraud has become a topical issue across the globe. Banks across the world are losing billions of dollars through fraudulent activities. Fraud has led to the downfall of entire organizations, massive investment losses, and erosion of confidence in capital markets (1).In Zimbabwe banking fraud has become serious issue as cases have been on the increase since the introduction of the multiple currency system. However, in developing countries like Zimbabwe, banks are the only major source of finance for firms (2); hence, their soundness has to be ensured. As such, it is crucial to investigate the reasons behind banking fraud and try to find ways of preventing it. Therefore, this research study focused on the causes of banking fraud in Zimbabwe.

Statement of the problem

Cases of banking fraud have been rising globally from insignificant levels in the 19th century to extremely high levels in the twenty first century. With time also, the losses incurred from each bank fraud activity have grown. Throughout these years bank regulators and other interested parties have tried to come up with measures that are intended to strengthen internal bank controls and to stop banking fraud through classifying it as a major operational risk event loss (3). However, these

measures have not been successful enough as banking fraud has remained a thorn within the global banking sector, this fact signified by the continuous collapse of banking institutions as a result of fraudulent activities mainly by internal staff members. As a result, questions have been raised on whether the issue of the recurrence of fraud within banks is just a result of weak controls or there is more to it for example inadequate training, inadequate technology to curb fraud or some other causes. This is an issue that has been debated globally .In Zimbabwe cases of bank fraud are on the increase and again blame has been placed on weak internal controls(4) within the banking system in Zimbabwe . However, is it just a case of weak internal controls? Are there no other causes besides weak controls within the banking system which have had an influence on the increased incidences of fraud? This is an area that has never been really looked at hence the study looked at clearly outlining the causes of fraud within banks in Zimbabwe.

Definition of terms and theoretical framework

The term fraud has many definitions. It can be any dishonest act or behaviour by which one person gains or intends to gain advantage over another person (5).It can also be misrepresentation, breach of trust, manipulation of books of accounts, fraudulent encashment of instruments like cheques, drafts and bills of exchange, unauthorized handling of securities charged to banks, misfeasance, embezzlement, theft, misappropriation of funds, conversion of property, cheating, shortages, irregularities (6). For the purposes of this study bank fraud is defined as dishonest act or behaviour by an employee within the bank, or by someone outside the bank with knowledge of loopholes within the bank which leads to the individual obtaining money, assets or other properties belonging to a banking institution.

In most cases, the occurrence of bank fraud largely depends on the internal control environment within a bank. This environment has to be understood by auditors and all those who are responsible for implementing the control function within all firms .Any conditions which are not right and which might lead to fraudulent activities should be noted and corrected (7).Indeed internal controls are critical in the prevention of fraud as symptoms of poor internal controls increase the likelihood of fraud (8).In addition , literature has sometimes overemphasized on strong internal controls as the panacea for bank fraud .As a result , the main advice offered in professional literature on fraud against a business is to put into place and to vigilantly enforce preventive controls (9).However , are internal controls alone good enough to deter banking fraud ?Research has shown that internal controls on their own cannot stop fraud. Internal controls are not always enough to prevent fraud because controls are designed to provide reasonable, not absolute assurance that something bad will not happen (10).

Research therefore, has to move from the viewpoint that bank fraud is an operational risk event caused by weak controls only as other factors also have to be considered. In certain cases it can be a result of unemployment and uneven spread of wealth within society (11) or lack of an effective internal audit staff at the company, frequent turnover of management or directors, appointment of unqualified persons in key audit or finance posts, customers reluctance to provide requested information or financial statements and fictitious or conflicting data provided by the customers (12).Fraud therefore , occurs in a "fraud friendly environment" (12) and this environment can be in the form of untrained staff, a demotivated workforce or inadequate staff inadequacy. In light of this, it was imperative to investigate the cause of fraudulent events within the sector and to try to give solutions on ways of tackling this problem.

OBJECTIVES

The objectives of the study were as follows:

Primary Objective

The primary objective of the study was to investigate the causes of fraud in banks in Zimbabwe.

Secondary Objectives

To investigate the primary objective, the study focused on establishing the strength of internal controls within banks as a secondary objective. It also focused on determining the level of employee motivation within banks as well as determining whether bank employees were adequately trained to detect fraud.

METHODOLOGY

Research design

The research adopted a descriptive survey research design. The descriptive survey design suited this research in that it provided the platform for measuring opinion on certain aspects of banking fraud thus, allowing the researcher to establish causal relationships between those aspects and banking fraud.

Study population

The study population was made up of all 21 licensed commercial and merchant banks in Zimbabwe as at 1 May 2009 and one regulatory body namely the Central Bank of Zimbabwe.

Sampling technique

The research adopted the purposive sampling technique. In this technique, the researcher handpicked banking institutions which had been reported to have fallen victim to fraud and those which had no reported fraudulent incidences. This technique was adopted as it allowed the researcher to select banking institutions that would provide the most valuable and accurate data to the researcher basing on the characteristics of the institutions selected and their relationship with the variables under study.Also, purposive sampling was used because it permits the selection of respondents whose qualities or experiences permit an understanding of the phenomena in question, and are therefore valuable. A sample of 10 commercial banks, 2 merchant banks and one regulatory body was selected.

Data collection

The following methods were used to collect primary and secondary data:

Primary Data

Primary data was collected using questionnaires and structured interviews. A single questionnaire was designed and 5 samples were administered to 10 of the banking institutions studied during the research. Of the 5 samples sent to each bank, two were meant for managerial employees within banks and the other for non managerial employees. In this case the researcher used the drop and pick method as most of the respondents did not have time to spare for interviews. The questionnaire had close ended questions in which the respondent had to pick his preferred choice of answers.

The questionnaire mainly focused on the following aspects

- Level of internal control practiced by banks.
- Level of staff motivation
- Fraud detection training
- Recommendations by respondents on ways to prevent fraud.

The questionnaire comprised questions which were close ended but had ranked responses for certain questions. Finally the respondents also had the chance to give their own opinion through a final open ended question. The questionnaire had nine questions which covered all the research areas.

Secondary data

Secondary data was collected through the use of articles on the internet, newspaper articles, journals, and other texts that had information relevant to the study. Secondary data was used to fill data gaps that primary data could not fill.

Data Analysis

Data collected was converted to numerical values .The numerical values represented the frequencies for the responses obtained from the questionnaires issued as well as the interviews carried out. These frequencies were then represented in percentage scores for each response to an area of focus specified on the questionnaire. The data in percentage form was then presented and analyzed in Tabular form, graphically, as well as in pie chart form so as to give a clear picture of the results obtained from the research.

RESULTS

This section presents the results of the research study.

Level of internal control practiced

A total of 12 questions were prepared to cover the measure of internal controls exercised within banks.

Dual responsibility

As shown in table 1below, all the respondents (100%) were of the view that bank managers involved more than two people in any transaction as it was a requirement within the banking sector that the principle of dual responsibility be followed for all banking transactions.

Table 1: Dual Responsibility

	Frequency	Percentage
Yes	45	100%
Total	45	100%

Source: Primary Data

Rotation of duties

Table 2 below shows that 58% of the banking institutions rotated their staff every six months and 42% did not rotate their staff during that period.

Table 2 Rotation of Duties

	Frequency	Percentage
Yes	26	58%
No	19	42%
Total	45	100%

Source: Primary Data

Daily Monitoring of accounts

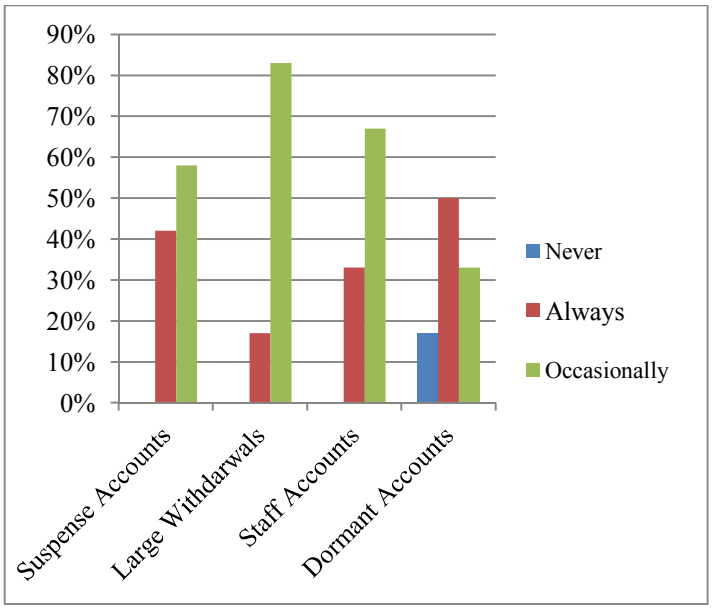

Figure 1 : Monitoring of Accounts

Source: Primary Data

As according to figure 1 above, showing the monitoring of the accounts, all the respondents said that they did check the suspense account though at varying intervals. 42% of the respondents' said that the account was checked occasionally and 58% claimed to be checking the account daily. The majority of the respondents (83%) were of the view that large sum withdrawals are always

scrutinized, 17% were of the view that they are occasionally monitored whilst none of the respondents claimed they never checked large sum withdrawals. Again, according to figure 1 monitoring of staff accounts was discovered to be not a daily routine. Although 67% of the respondents were of the view that staff accounts are always checked daily, 33% of the respondents claimed that the checks were not always done daily but occasionally as routine spot checks. The figure also shows that dormant accounts are not monitored at all by 17% of the respondents. 50% of the respondents claimed that dormant accounts are monitored occasionally and only 33% said dormant account are always monitored.

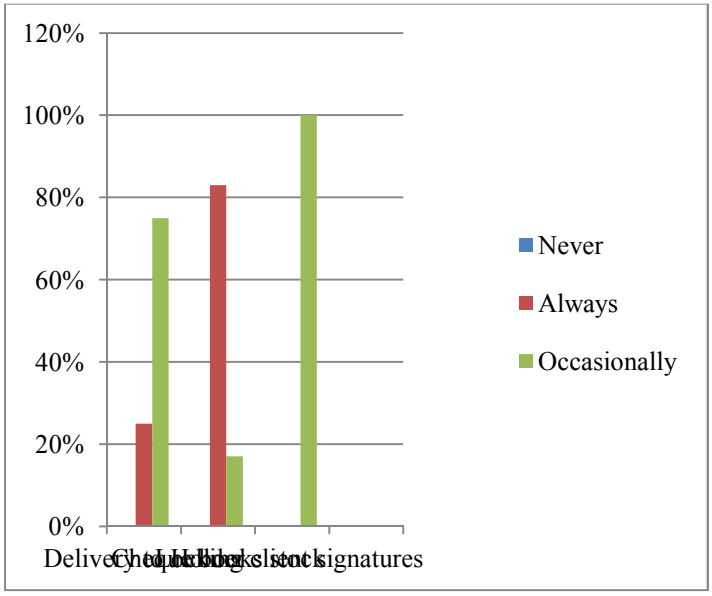

Figure 2: Cheque book controls

Source: Primary Data

According to figure 2 above, 75% of the times delivery of a cheque book is done to the account holder only. However, full compliance is not done in this aspect of cheque book administration as according to the same figure, 25% of the times a cheque book is delivered to a person who is not the account holder. Also, the study found out that 83 % of the respondents occasionally check stock of cheque books and bank drafts available. Only 17% of the respondents said they always keep track of stock of cheque books and bank drafts available. Furthermore, in the locking of specimen signatures overnight, there was 100% compliance as all the respondents said they do keep specimen signatures under lock overnight.

Review of quality of loans

Table 3 below shows results on the periodic reviews of the quality of loans that are issued by banks in Zimbabwe and the checking of the possibility of insider loans.

Table 3 Review of quality of loans

	Frequency	Percentage
Never	8	17%
	30	67%
Always	7	16%
Total	45	100%

Source: Primary Data

As shown in table 3 above, the study found out that 17% of the respondents never check the quality of loans that have been issued 67% check occasionally and only 16% always periodically check on the quality of loans issued by their banks.

Monitoring transfers and balancing Books

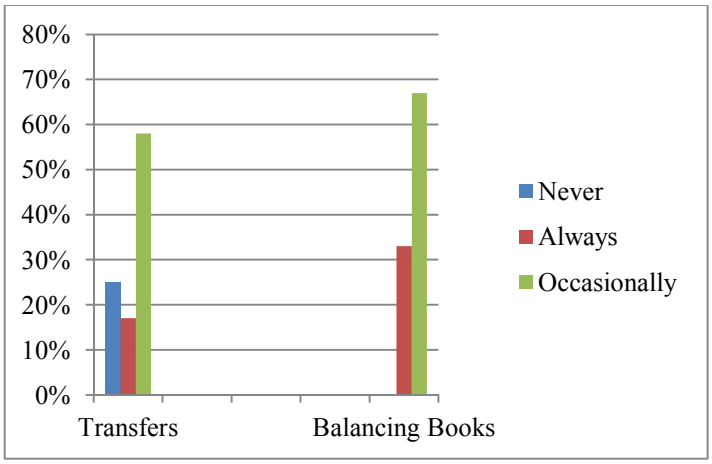

Figure 3: Transfers and Balancing Books

Source: Primary Data

Figure 3 above shows the rate of monitoring bank transfers by banks and responses on periodical balancing of books. 25% of the respondents said they never check interbank transfers whilst 58% said they occasionally check for interbank transfers that are done without the required authorization and only 17% said they always check interbank transfers so as to avoid any transfers that may be done without authorization. In addition, the study found out that not all banking institutions engage in the periodical balancing of their books. Although the greater part of the respondents (67%) said

they always do balance their books periodically, a significant portion (33%) said they occasionally balance their books periodically, thus leaving room for unreconciled items.

Security of internet banking

Table 4: Security of internet banking site

	Frequency	Percentage
Secure	37	83%
Not Secure	8	17%
Total	45	100%

Source: Primary Data

Table 4 shows respondents views on the security of their banks` internet banking sites. The study found out that 83% of the respondents believed that their banks internet banking websites are secure enough such that they will not be exploited by external fraudsters. 17% believed their internet banking websites are not secure enough to deter fraud.

Fraud prevention score

The overall compliance scores on internal controls were calculated for each category and were as shown below:

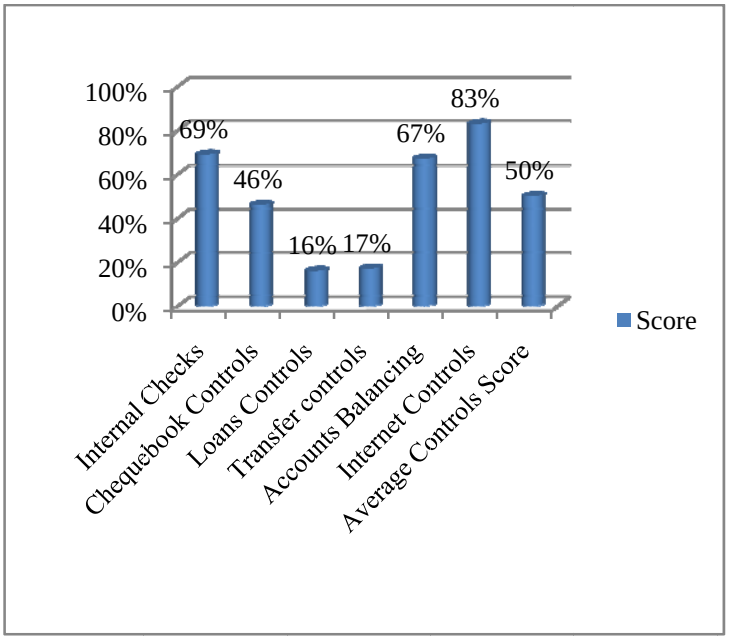

Figure 4: Fraud Prevention Score

Source: Primary Data

Figure 4 shows the overall compliance scores obtained for each category of controls. The figure shows that internet security attained the highest score of 83%. Internal checks attained the second highest score of 69%. The accounts balancing section attained the third highest compliance score of 67%.Cheque book controls had an overall mark of 46%. Transfer controls and loans controls had the lowest scores of 17% and 16 %, respectively. The overall score for internal controls was 50%, indicating weak controls within the banking sector.

Bank fraud training

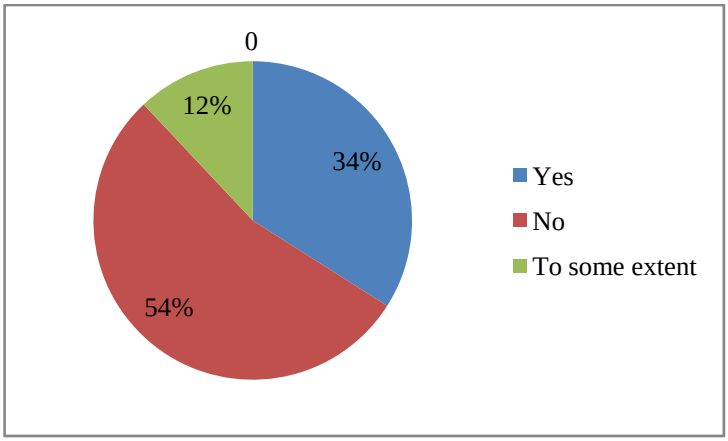

Figure 5: Fraud Training

Source: Primary Data

Figure 5 shows research findings on fraud related training that bank employees have gone under.54% of the respondents indicated that they had not undergone any fraud related training.34% stated that they had undergone fraud related training whilst 12 indicated that to some extent they had been trained to detect and prevent fraud.

Level of staff motivation

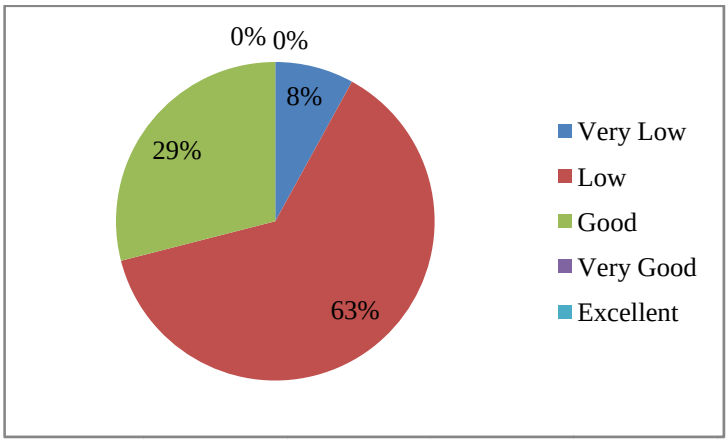

Figure 6: Staff Motivation

Source: Primary Data

Figure 6 shows the findings on the levels of motivation in the banking sector. 63% of the respondents were of the view that employee motivation is low, whilst 8% indicated that employee motivation is very low. Only 29% of the respondents were of the view that employees motivation is good. None of the respondents were of the view that the level of motivation is either very good or excellent.

4.4 Suggested ways of preventing fraud

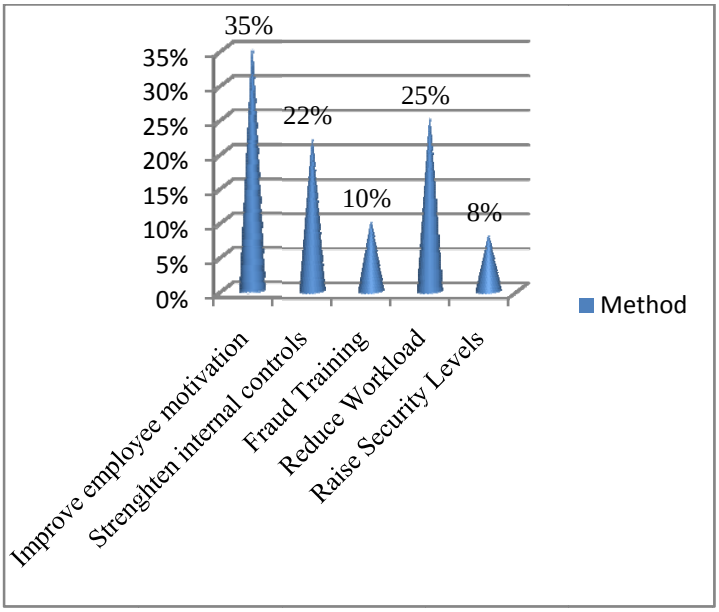

Figure 7: Ways of Preventing Fraud

Source: Primary Data

Figure7shows the suggested responses on ways of preventing bank fraud .35% of the respondents were of the view that there is need to improve employee motivation to prevent fraud.22% advocated for improvement in internal controls, 10% suggested fraud related training for employees, and 25% were of the view that reduced workloads would reduce fraud whilst 8% suggested improvements in the security levels within banks as a way of reducing fraud.

5.0 DISCUSSION

here is need for continuous process of monitoring of the control environment to ensure that risks such as fraud are noted and the problems arising thereof quickly addressed (7).Good internal controls are therefore needed in the prevention of fraud.

The results obtained for dual responsibility show that banks are complying with the principle. This is mainly a result of dual responsibility being a basic requirement for all banking operations. This, hence, minimises the chances of manipulation by of transactions any single individual.

Findings of the study indicate that the principle of periodic staff rotation is not being fully observed within banks. This reflects negligence on the part of bank managers of the risk of internal fraud by staff who would have overstayed in a specific job position without being shifted or moved to another position. An employee who stays in one job position for too long will tend to know a lot about the strengths and weaknesses of internal controls involving that job hence, by not rotating employees, bank managers have created a fraud friendly environment. This finding is supported by the view that the head of the branch holds the responsibility for ensuring adherence to prescribed systems and procedures in preventing fraud (13).

According to the research findings 58% of banks check the suspense account daily whilst 42 % check it occasionally. Compliance on internal checks with regard to the suspense account is a bit slack as the suspense account is supposed to be checked daily for any suspicious transactions. Occasional monitoring of the suspense account signifies partial implementation of control measures within banks in Zimbabwe which again has led to the development of a fraud friendly environment in banks in Zimbabwe. This finding is in agreement with a previous research which found that inadequate controls account for about 60% of fraud cases (14). However, this study was more focused on corporate fraud rather than being focused n banking fraud only.

With regards to the monitoring of large withdrawals, the study found out that the degree of compliance with respect to this is very high hence; chances of money laundering and other

fraudulent activities involving large sum withdrawals are low. The study also found that some staff accounts are not checked daily but are checked occasionally. This indicates a moderate level of control on an aspect that may lead to internal bank fraud .It also shows that there is a chance that internal fraud by members of staff may occur without it being discovered on the day of occurrence as a result of lack of checking on the turnover in staff accounts. This finding is in line with the finding that occupational fraud and abuse accounts for USD$600 Billion per year (15). In this regard, it can be seen that employee fraud can occur in any organization including banks regardless of any sophistication. This research was however, carried out in the context of an American business setup/society where the business environment is different from Zimbabwe. In addition, the finding of the research study that dormant accounts are not being checked reflects a serious weakness in internal checks which can be exploited in carrying out internal fraud.

The research found out that full compliance is not done in the aspect of cheque book administration as according to the research findings ,25% of the times a chequebook, is delivered to a person who is not the account holder thereby increasing the chances of external fraud in the form of cheque fraud. This finding agrees with the finding that cheque fraud occurs mainly in company accounts and is invariably perpetrated by employees within the company who have access to cheque books (16).The study also found out that the stock of cheque books within banks is not being properly monitored which reflects a serious flaw with respect to cheque book and bank drafts management as not keeping track of these items opens up the banks to both internal and external fraud. The results also indicate that specimen signatures of clients are well secured within banks as all there was 100% compliance with locking specimen signatures because “forgery may be in the form of signatures which are altered to suit the needs of the fraudster” (16).

According to the study findings, 17% of the respondents never check or periodically review the quality of loans that have been issued out.67% check occasionally and only 16% always periodically check on the quality of advances and loans. This means most banks face the risk of losing funds due to loan fraud as there is no serious attempt to verify the character and antecedents of the borrower. The end user of funds borrowed is not checked or verified. It also means that most banks do not take adequate collateral to cover themselves against default risk as no proper analysis of the borrower is done hence in such cases the chances of loan frauds are very high. This also leaves banks susceptible to insider loans which in the end might end up being non performing loans on the banks books. In this case, loan procedures are not being followed .This finding agrees with the finding that the probability of embezzlement is enhanced by lack of timely or periodic review,

inspections, and follow-up to assure compliance with company goals, priorities, policies, procedures (17).

The results indicate there is total negligence by managers in terms of monitoring interbank transfers despite the fact that a lot of fraud is committed using interbank transfers. This means some transfers are being done without proper authorization, enhancing the chances of fraud. In terms of balancing books, the results indicate that accounts and

Reconciliations are not being carried out on a regular basis leaving room for unreconciled items hanging hence; any frauds committed are not noticed. If periodical balancing is not done regularly , it also means that any suspicious transactions noticed will not be given the attention they deserve as one will be in hurry to cover up for the upcoming period hence in such a case fraudulent activities stand the chance of being just swept under the carpet .

The study results show that most of the respondents were of the view that their banks internet banking websites are secure enough such that they will not be exploited by fraudsters. However not much can be drawn from this as incidents of internet banking fraud have not been high in Zimbabwe and this could be more attributed to the very low levels of internet banking activity within Zimbabwe and the low values in terms of dollars that one has access to whilst transacting on the internet in Zimbabwe rather than the security of the internet sites. Also, the study could have been clearer on the categories of security it referred to for example issues to do with password protection, privacy of information, hacking of account information, virus threats and got responses on the security levels of each of these. However, the study managed to bring out the level of confidence banks have in their internet banking sites.

Findings of the study indicate an overall score of 50% for internal controls which is a very low mark for banks. Banking institutions are supposed to be institutions that have employees who are vigilant in terms of maintaining internal checks so as to totally safeguard depositors' funds. The low score is a result of lapses in different areas of the internal control units within banking institutions. This reflects weak controls within banks. This is in line with the findings of a previous research that weak controls account for 48% of all fraud cases (18).

The study found out that 54% of bank employees have not undergone any fraud prevention training. Only 34% have gone under fraud training. This means most of the employees do not have the skill to detect fraudulent activities and have not been taught how to prevent it. Lack of fraud related training may also explain the general lapse in internal controls as most of the employees within

banks do not have the capacity to effectively check for any suspicious transactions as they are supposed to do. Also it should be noted the fact that some respondents were of the view that to some extent they had received bank fraud related training , which means that they were not sure whether the training was adequate or not. Previous studies have shown that training improves the capabilities of employees by enhancing their skills, knowledge and commitment towards their work (19).

The research study found out that staff morale within the banking sector is low. 63% of the respondents in the research were of the view that staff motivation is low meaning that the majority of employees within banks are not happy with their working conditions. Clarification on the levels of staff motivation was obtained through the interviews carried out and it was discovered that the perception of employees within the sector is that they are being overworked but not getting a fair remuneration in return. The other source of demotivation noted was that bank employees are worried about their future since the banking sector is struggling at the moment and hence, most banking employers have not come out in the open to guarantee their employees that they will remain open for the foreseeable future. Although the majority of the respondents said staff motivation was low, the view of the other 29% that it was good can be attributed to a section of employees within the sector whose welfare is more desirable than that of other employees especially the management. The study did not however give the opportunity to respondents to highlight ways in which they think their motivation can be improved.

The research found out that improving employee motivation is the most preferred way of preventing fraud. This finding maybe a result of the fact that the respondents were employees from the banking sector hence they would recommend a prevention measure which improves their wellbeing. However this finding agrees with findings from previous research which indicate that the more dissatisfied an employee is, the more likely he is to be involved in a criminal activity (10). The second most preferred way is to strengthen internal controls whilst the others included reducing the workload for employees, improving the level of security within banks, and sending employees for fraud training. These ways however were just the respondents' opinions and were not based on any research facts.

CONCLUSIONS

Conclusions were drawn on each finding of the research study and were set out as below.

The research concluded that controls within banks are weak and banking fraud that occurs in banks in Zimbabwe is partly a result of weak controls and procedural lapses that occur within banks in Zimbabwe. Banks rules and procedures are not strictly adhered to as a matter of control.

The research also concluded that bank employees are not well trained to prevent bank frauds. As a result it can also be concluded that bank employees do not have the skill to detect fraud before it occurs and the ability to follow procedural guidelines which prevent fraud.

The research concluded that staff motivation within banks is so low that it has contributed to staff apathy and in turn also contributed to bank fraud in the form of internal fraud.

From the results of the research study, it can be concluded that banking fraud in Zimbabwe is not only a direct result of weak controls but is also a result of other factors. The other factors include lack of fraud related training and, low staff motivation.

RECOMMENDATIONS

The research study makes the following recommendations to the various stakeholders concerned with bank fraud:

Banks should strengthen their internal control systems. Banks should ensure there is separation of duties, daily checking of sensitive areas like suspense accounts, staff accounts, and dormant accounts. Banks should also ensure that their employees strictly follow stated procedures in all instances and any deviation from stated procedure should not be tolerated. There is also need to ensure that the control systems in place are regularly reviewed to see whether they suit developments within the sector. This is in line with the view that any conditions within the control environment which are not right and which might lead to fraudulent activities should be noted and corrected (7).There is need for a fraud related training programme for banks. Through training employees become more aware of their relevance, their importance and the need for them to adhere to prescribed rules and procedures. Training also improves employees' fraud detection skills and leaves employees with an increased sense of responsibility. This recommendation is in line with findings of previous research which indicate that training improves employees' capabilities by enhancing their skills, knowledge and commitment towards their work (19).Training bankers helps not only in developing job related skill but also maximizes the performance potential of bankers and provides them the sound knowledge and understanding of banking practices and principles (20).Banks also need to improve the motivation level of their staff. A good salary structure and

excellent working conditions which can help to a great extent to reduce the temptation to commit fraud need to be put in place. In addition, management should not hesitate to come to the aid of employees any time there is a genuine financial request particularly in emergency situations. Such assistance not only eliminates the tendency to defraud the organizations, it helps to cultivate a group of dedicated and highly productive workforce. This view is supported by findings which show that employees with low levels of job security, power and income have high aspirations to engage in illegal activities within the organization (21).

Banks regulators should carry onsite and offsite surveillance of banking institutions to ensure that fraudulent activities by bank staff are not knowingly hidden from the public. Banks are reluctant to report frauds because it would seem like washing its dirty linen in public but in cases where the fraud involves internal members of staff the public should be notified as they are the real owners of the funds at risk hence, deserve to be in the light on how safe their funds are. Bank regulators should regularly review rules and guidelines for all banking institutions in line with new developments within the banking sector. These rules and procedures should be aimed at preventing chances of banking fraud occurring for example they can put in place a request for an analysis of loans issued to be submitted every week to reduce the chances of insider loans .

Government is encouraged to enact laws that ensure there is protection of depositors' funds in the case of banks losing depositors funds to frauds. There should be insurance for depositors' money lost through bank frauds. Government is also encouraged to allow for the enactment of laws that discourage fraudulent behaviour for example laws that ensure fraudsters get severe punishment for committing fraud.

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SAMPLE RESEARCH QUESTIONNAIRE

SECTION A: GENERAL INFORMATION

1. Name of bank attached to.....
2. Position held within organisation (tick appropriate)

Managerial ☐ Non Managerial ☐

SECTION B: LEVEL OF INTERNAL CONTROL

3. Is there dual responsibility for every transaction within your bank? (tick appropriate)

Yes ☐ No ☐

4. Is there rotation of duties within your bank? Tick appropriate)

Yes ☐ No ☐

5. Please indicate the frequency with which the following activities are done within your bank (tick appropriate)

a. Monitoring of Suspense Account

Never ☐ Occasionally ☐ Always ☐

b. Monitoring of Large Withdrawals

Never ☐ Occasionally ☐ Always ☐

c. Monitoring of Staff Accounts

Never ☐ Occasionally ☐ Always ☐

d. Monitoring of Dormant Accounts

Never ☐ Occasionally ☐ Always ☐

e. Delivery of cheque books to account holders only

Never ☐ Occasionally ☐ Always ☐

f. Checking stock of cheque books available

Never ☐ Occasionally ☐ Always ☐

g. Locking client specimen signatures overnight

Never ☐ Occasionally ☐ Always ☐

h. Reviewing quality of loans issued by the bank

Never ☐ Occasionally ☐ Always ☐

i. Checking transfers done without authorisation

Never ☐ Occasionally ☐ Always ☐

j. Periodical Balancing of books of accounts and reconciliations

Never ☐ Occasionally ☐ Always ☐

SECTION C: STAFF MOTIVATION AND TRAINING

7. How do you rate the level of staff motivation within your organisation at present? (tick appropriate)

Very Low ☐ w ☐ d ☐ ry Good ☐

Excellent ☐

Explain.....

8. Have you undergone any fraud prevention training

Yes ☐ No ☐

9. In brief suggest ways banking fraud can be tackled in Zimbabwe

.....

Where did our money go? Answering the questions behind loss of value to pensioners in Zimbabwe after multi-currency adoption.

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ABSTRACT

The turn into the year 2009 brought dollarisation of the Zimbabwean economy which saw pension funds assets and liabilities being converted into the United States dollar (USD). The derived pension values fall short of 'pensioner/policyholder reasonable expectations' (PRE). This research defines PRE and explores the specific factors that led to the demise of pension values over the years 1997- 2008. SPSS analysis of questionnaire responses and Microsoft Excel analysis of annual asset returns and exchange rates reveal; the hyperinflationary economy, prescribed asset regulations, use of the Old Mutual Implied Rate (OMIR), pension products design and the contagion effects of the 2003/04 banking crisis as the lead factors against pension build up. The researchers recommend some regulatory amendments, improved client communication and advisory, PRE guidelines, pensioner compensation, accurate benefit projections and voluntary contributions by pensioners to regulators and pension funds.

Key words: dollarisation, hyperinflation, prescribed assets, policyholder reasonable expectations

INTRODUCTION

Zimbabwe fully adopted the multi currency system in January 2009 as pronounced by the then acting minister of finance Honourable Patrick Chinamasa, [1]. The Pensions and Provident Funds Act PART IV section 16 (2) of Zimbabwe, [2] meant that pension funds would declare their statements of assets and liabilities in United States dollars (USD). Part I (2) of the act describes a "pension" to include an annuity (regular stream of cash payments) acquired through a fund; while a "pension fund" means any fund the principal object of which is to provide for the payment of a pension to a person who is or has been a member of the fund on his/her retirement.

In its simplest form Princeton University online dictionary, [3] defines a pension as a post-retirement benefit that an employee receives from his/her employer's retirement plan whose main aim is to provide a regular source of subsistence to the 'non working' retired. The above definitions create an expectation on the part of a policyholder/pensioner (to be used interchangeably in this paper) for one to receive some post retirement income commensurate with the contributions made during one's working years as explained by the StateFarm insurance website [4].

Policyholders' reasonable expectations (PRE) in South Africa

The Financial Services Board of South Africa Interpretation Note 1 of 2010 [5] of their law says; '…accrued liabilities of pensioners represent the present value of pensions in courseof payment as at the valuation date. Such present value must take into account therights and reasonable benefit expectations of pensioners, including, *inter alia*, any right or reasonable expectation in regard to increases in terms of the pension increase policy'.

Policyholders' reasonable expectations (PRE) in the United Kingdom

In his pioneering work, Skerman [6] wrote; 'it would be unsatisfactory not to take some account of the policyholders' reasonable expectations when determining the value of the liabilities'. From this the United Kingdom (UK) Financial Services and Markets Act [7] uses the term `treating customers fairly' and guided by it, the UK Financial Services Authority (FSA)'s 6th principle [8] is laid down as follows:

- A firm must pay due regard to the interests of its customers and treat them fairly.
- A firm must conduct its business with integrity.
- A firm must pay due to the information needs of its clients and communicate to them in a way that is clear, fair and not misleading.
- A firm must manage conflicts of interest fairly, both between itself and its customers and between a customer and another client.
- A firm must take reasonable care to ensure the suitability of its advice and discretionary decisions for any client who is entitled to rely upon its judgment.

In the famous UK Equitable Life case, Lord Penrose [9] highlights that since the emphasis is on policyholders and potential policyholders, it is reasonable to infer that reasonable expectations are a function, at the very least, of; information communicated to the policyholder or potential policyholder, by whatever means the particular office elects to employ, and related to the offices policies and practices. When joining a pension fund workers are told they are saving for retirement and then failure to provide on retirement will be failure to meet reasonable expectations. Literally

policyholders' reasonable expectations mean keeping the man on the street satisfied by the value provided by insurance companies. However, the magazine of the actuarial profession [10] criticises Lord Penrose's interpretation of PRE citing the use of scenarios and probabilities in the design and pricing of insurance products.

Impact of the macro economy on Pensions value build up

Fultz and Pieris [11] acknowledges the dynamic interplay between social security schemes and their environment in which the latter in economic sense determines the level of resources available for social security and their distribution among the population, while social security influences rates of poverty, the health and longevity of the workforce and the popular support enjoyed by the government. They concur with Bulow [12] and Watkins [13] that financial planning becomes difficult during times of inflation with the pensioners of the day being more adversely affected than current employees.

The hyperinflation years in Zimbabwe (2004-2008) made salaries, savings and pension contributions fall in worth with the passing of each day as observed by Hoto [14]. Insurers continued to come up with new products aimed at matching the hyperinflation environment and in 'trust' Zimbabweans bought those new products unaware that they would fail and the conversion values turned out to fall short of the expectations of policyholders/pensioners.

Zimbabwe's Prescribed Assets Regulations

The Zimbabwean Insurance Act chapter 24:07, [15] requires insurance companies to hold part of their funds in 'prescribed securities' which are stated (in Part I of the Act) as (a) stocks, bonds or other like securities issued by the State, a statutory body, or a local authority, and includes, in relation to non-life insurers and the class of insurance business carried on them, treasury bills, or similar short-term bills issued by a statutory body or local authority; and (b) investments approved or prescribed by the Minister from time to time for the purposes of this definition;… and the proportions of the insurance funds which shall be held in prescribed securities so specified. It was on the basis of this legislation that the Reserve Bank of Zimbabwe (RBZ) Governor Dr. G. Gono, [16] directed all insurance and pension funds to comply with their prescribed asset requirements by end of November 2008.

Masilela [17], asserts that 'prescribed assets are a method through which government intervenes in the market to force or influence investment resources into particular sectors of the economy. When you have strict prescribed assets government literally sets the limits with which people or investors have to invest and the specific sectors in which they have to invest irrespective of the return.' The

same interpretation is construed from Legat [18], while Padayachee [19] and White & Glaser [20] views prescribed assets as a way of 'socially responsible investment' within an economy.

In the wake of hyperinflation, most pension funds had the non prescribed portion of their assets heavily invested in stocks on the ZSE. Their actions were in line with the pioneer views from Fisher [21], that 'stock represents a hedge against inflation'. However the fact that prescribed assets requirement of 35%, 30% and 25% for pension funds, long-term insurers, and short-term insurers respectively [1], had to be rebalanced on a month on month basis meant that while the other portion assets earned a market return that outpaced inflation the prescribed assets were wiped to zero and had to be further boosted thereby depleting the accumulated value as witnessed by Buckle [22].

Developments in the Financial Sector

The period 2003 to 2004 saw a number of banks being forced to close down in what has become to known as the Zimbabwean Banking Crisis and the main cause being poor credit risk management. The RBZ 2004 annual report [23] states that number of financial institutions declined from forty (40) as at 31 December 2003 to twenty nine (29) as at 31 December 2004. The crisis made pension funds shift their interest bearing funds from the high yielding (banks') money market instruments to the low yielding treasury bills. The period 2004-2008 brought an exchange rate crisis characterised by cash shortages and the dominance of the parallel exchange rate over the official one. The RBZ responded by introducing tight money laundering controls that led to longer clearing periods for cheque and real time gross settlements (RTGS) transactions that had a severe negative impact on the ZSE trading.

In response, pricing on the ZSE shifted towards full reliance on the fungibility of the multiple listed Old Mutual Plc shares described in the 2010 ZSE handbook [24]. Dr G. Gono [16] condemned 'The practice by the ZSE where Old Mutual shares would deliberately be traded first during the two call-over slots to set the trend for all the other counters. Such practices were tantamount to adverse indexing of the ZSE to spurious speculative sentiments surrounding the Old Mutual counter via the parallel foreign exchange market (termed the Old Mutual Implied Rate (OMIR))'. The use of the OMIR by the ZSE led to wild share price increases/decreases with no fundamental basis in respect of actual developments at the relevant companies. The implementation of the memorandum led to the suspension of trades on the ZSE.

OBJECTIVES OF THE STUDY

This study is the first in trying to explain to the Zimbabwean public and the world the answers to the demise of pensions and other forms of savings and investments. The research contributes to the

literature in the following ways. First, the researchers draw parallels with SA and UK regulations to provide evidence on the violations of PRE during the transition to the USD of accumulated pensions. Despite outcries from both the public and government, the Zimbabwean legislation is silent on the subject of PRE. Secondly, they contribute to the national debate on the subject of the erosion of accumulated pension values in Zimbabwe by examining the interplay between the inflationary environment, the regulations on prescribed assets, the resulting valuation of pension assets in a bid to enlighten parties to the blame game between the government and the insurers. Thirdly, this paper assesses the post USD evolution of value in a bid to evaluate if a moratorium on postponing the time to effect conversions would have allowed pensioners to benefit from the resulting value appreciations especially for the listed stocks as observed by Legat [25].

Secondary objectives

This research traces the path followed by the pensioners' contributions over the period 1997-2009 in a bid to answer the 'loud' national question 'where did our money go?' The researchers carry out a critical analysis of the hyperinflation, asset performance, regulations on prescribed assets, foreign exchange markets and OMIR, pension products and the transition to the USD in light of PRE and guided by the following secondary objectives.

1. To define the term policyholders' reasonable expectations and prove that derived values did not meet policyholders' reasonable expectations (PRE)
2. To demonstrate the impact of hyperinflation, prescribed asset returns and other factors on the value of pensions over the period 1997-2009
3. To objectively asses the roles played by the government and insurance companies in their contributions to the pensions demise.
4. To draw conclusions and recommendations aimed improving the future of pensions in Zimbabwe.

METHODOLOGY

Both explanatory and descriptive research design methods were used to identify the root cause of the pension values demise in Zimbabwe. To get a more in-depth view of the problem as the researchers explored each and every identified research problem based on a descriptive research design.

Data Collection and Analysis

This study took a survey approach hence the use of a carefully designed and standardized questionnaires and in-depth interviews that allowed respondents to answer certain collated questions to secure the desired information. For the purpose of this research, Actuarial specialists, Pension fund trustees, Pensioners and Pension administrators from Harare and Bulawayo were identified as the defined target population.

In addition to the questionnaire responses, they collected annualised data for inflation, the ZSE returns and market capitalisation, TBs, government bonds, the Old Mutual Plc London Stock Exchange (LSE) share price, the ZWD/USD Exchange rates (official, parallel and OMIR), and carried out various manipulations to come up with trends, real returns (above inflation) and projected pension accumulations. Questionnaire responses were analyzed using the Statistical Package for the Social Sciences (SPSS) version 16.0, while secondary data and some SPSS output was analysed using Microsoft Excel.

How Pension Conversion Method Was Done

The following formula was used to calculate the USD cash **payout** given to pensioners;

Asset share = (Individual accumulated credit / Total accumulated credit) * 100

USD **Payout** Value = Asset share * (USD assets less reserve)

Funding level = (Assets / Liabilities)*100

Accumulated credit is an accumulation of past contributions using fund interest earned by the fund and was based on the asset share.

The researchers illustrate in Appendix I how the accumulated credit (total liability) was derived by generating random numbers representing individual accumulations and multiplying by 10,000.

Ethics Statement

This research made use of primary data that already has ethical documentation and did secondary analysis. Any sensitive company and individual specific data gathered from interviews and questionnaires was treated with strict confidentiality and experiences of individual companies masked beyond specific identification by future researchers and users of this paper.

RESULTS

The research results are based on completed questionnaire responses from 126 pensioners, 8 actuarial specialists, 20 pension fund trustees and 15 insurance practitioners and 10 interviews equally split between actuarial specialists and insurance professionals, representing 72%, 80%, 90%, 75%, and 71% respectively of the set target sample of respondents and interviewees. Where data could not lend itself to statistical analysis, content analysis was used especially in cases where respondents either gave suggestions or expressed their opinions. This section presents key findings of the research.

Whether Derived Pension Values Meet PRE

Responses to questions addressing PRE by all the above mentioned groups of respondents were mixed with virtually all pensioners claiming that the values given to them 'fall short of their expectations'. While 70% of the other remaining groups were of the view that derived pension values meet PRE (as it was outside the insurer's control and that the environment was evidently bad), 10% were stuck in the middle and the remaining 20% taking the popular 'pensioner' opinion.

Factors Leading To Low Pension Values.

The research reveals the adverse impact of inflation on pensions with 97% of pensioners (agree – strongly agree) to lay the blame on the Zimbabwean economy at large for the loss of their value. The blame on regulation on prescribed assets is high at 70% among professionals who were involved in the daily running of insurance and pension funds.

The pensioners however partially exonerate the insurance companies and pension funds, sanctions and the specific products with relatively low blame levels of 29%, 27% and 14% respectively. Among the professionals, the conversion method used is questioned with 20% arguing that insurance companies did not make an effort to explain details of how they did the conversion because the method was flawed especially on the exchange rates used and property valuation methods as shown in the blame on dollarisation. The overall picture of the consolidated statistics is as shown in Figure 1.

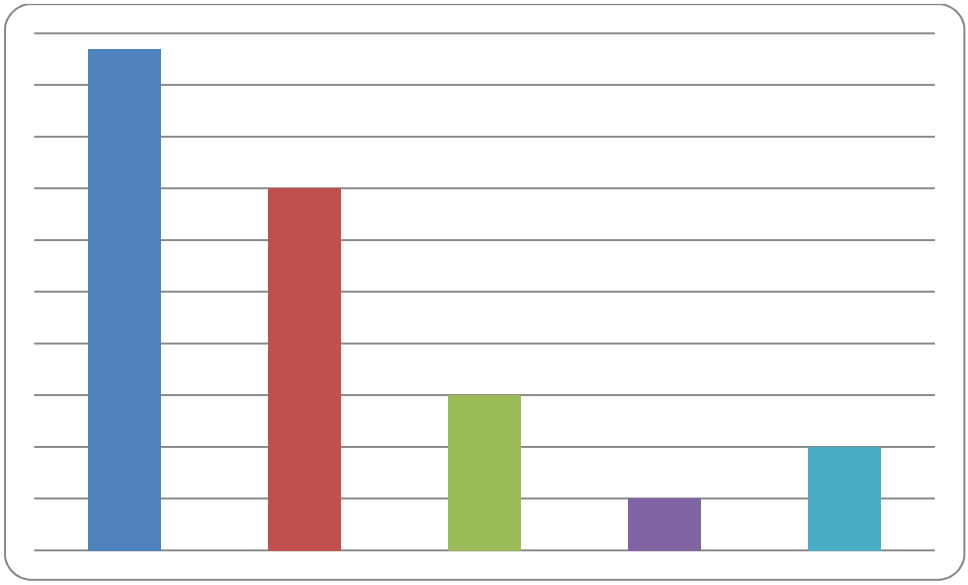

Figure 1 Factors ascribed by participants as leading to low pension values.

Source:SPSS and MS Excel Analysis of Primary data

The Impact of Prescribed Assets on the Accumulation of Pension Values

Comparisons of real returns from the ZSE and the prescribed assets (TBs and The 5 year government/municipal bonds) in Figure 2 shows that the prescribed assets performed negatively from 1998-2008 thereby destroying value on the proportion funds invested in them.

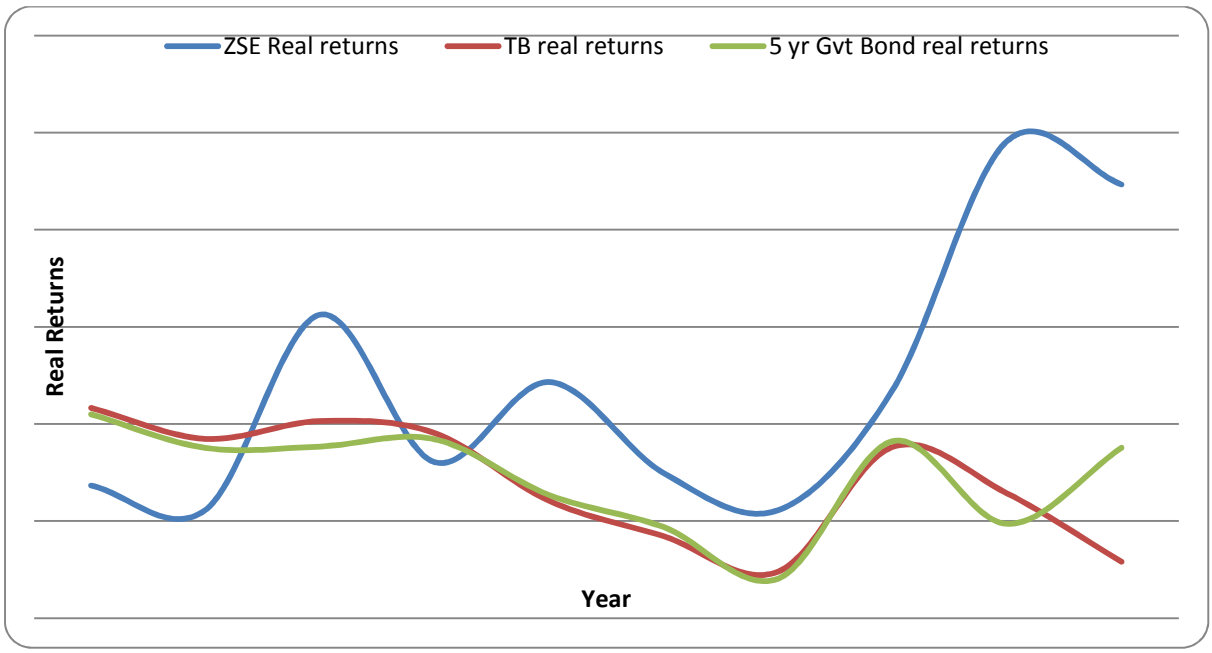

Figure 2: Real returns from selected Investments (1997-2006)

Source: MS Excel Analysis of Secondary Data

Value based Impact of Prescribed Assets on the Accumulation of Pensions

Comparisons in Figure 3 compares value accumulations for three investment portfolios; first made up of (65% ZSE/Market and 35% TBs), second made up wholly of the ZSE and a third one with all investment in TBs based on a nominal $100 at the end of 1996. The graphs show that the weighed portfolio would have fallen to $20 in 2004 before closing at $56 at the end of 2006. The trend suggests a marked negative impact during the build up to banking crisis of 2003/04. Although the ZSE performed quite well in the post 2004 years, the real returns were to be wiped out by the 231 million percent (231,000,000,000%) official inflation figures by midyear 2008.

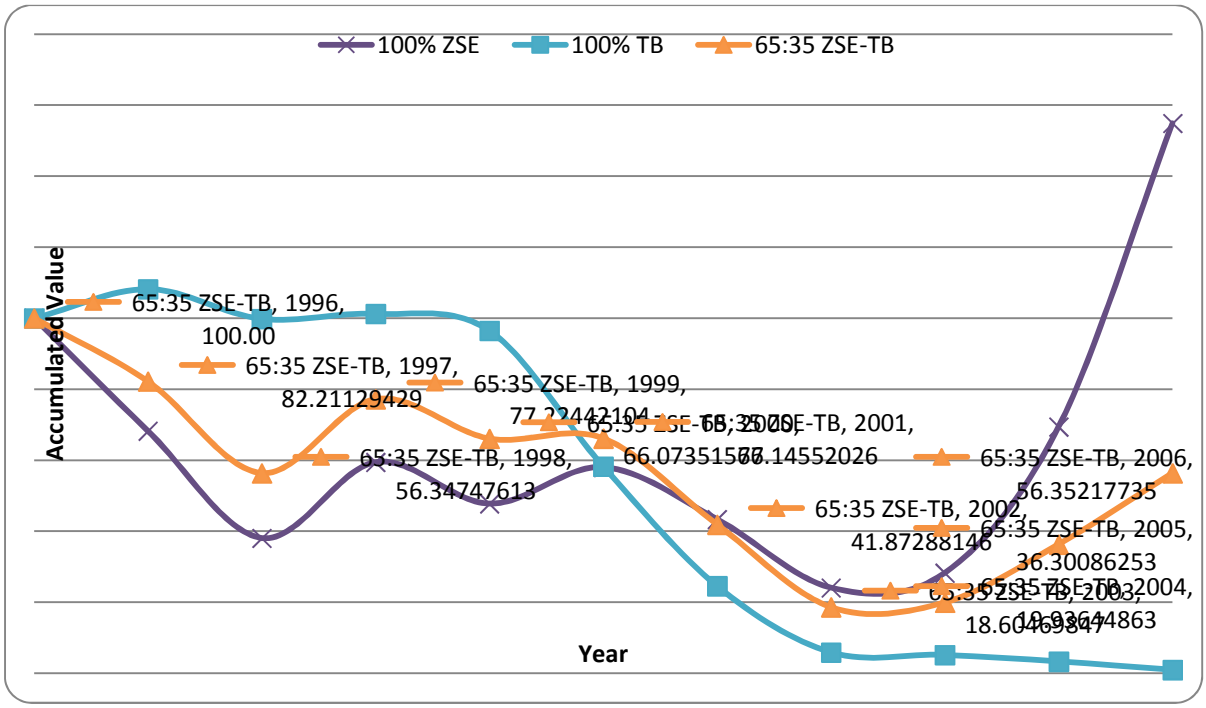

Figure 3: The Impact of Prescribed Assets on the Accumulation of Pension

Source: MS Excel Analysis of Secondary Data

Impact of the OMIR and depressed opening USD ZSE stock prices

Although the above section 4.3 gives an indication of some possibility that 'had the Pension fund been wholly invested in the ZSE some value could have been preserved for the pensioners', the events of 2008 as shown in Figure 4, indicate otherwise due to the following:

1. All investments in cash and interest bearing investments could not be redeemed following the adoption of the USD.
2. The ZSE market capitalization (a proxy of real returns) took a nose dive as the adverse effects of using the OMIR began to show.

Thus Figure 4 shows that due to regulations regarding pension fund valuations, most pension fund valuations completed during early 2009 gave depressed values of assets and hence low pensioner's accumulated values. Since Zimbabwe suffered from a crippling liquidity crunch post dollarisation, the pensioners wanted their dues but the payout values obtained (Value of listed stock + Non-cash investments) were rather depressed.

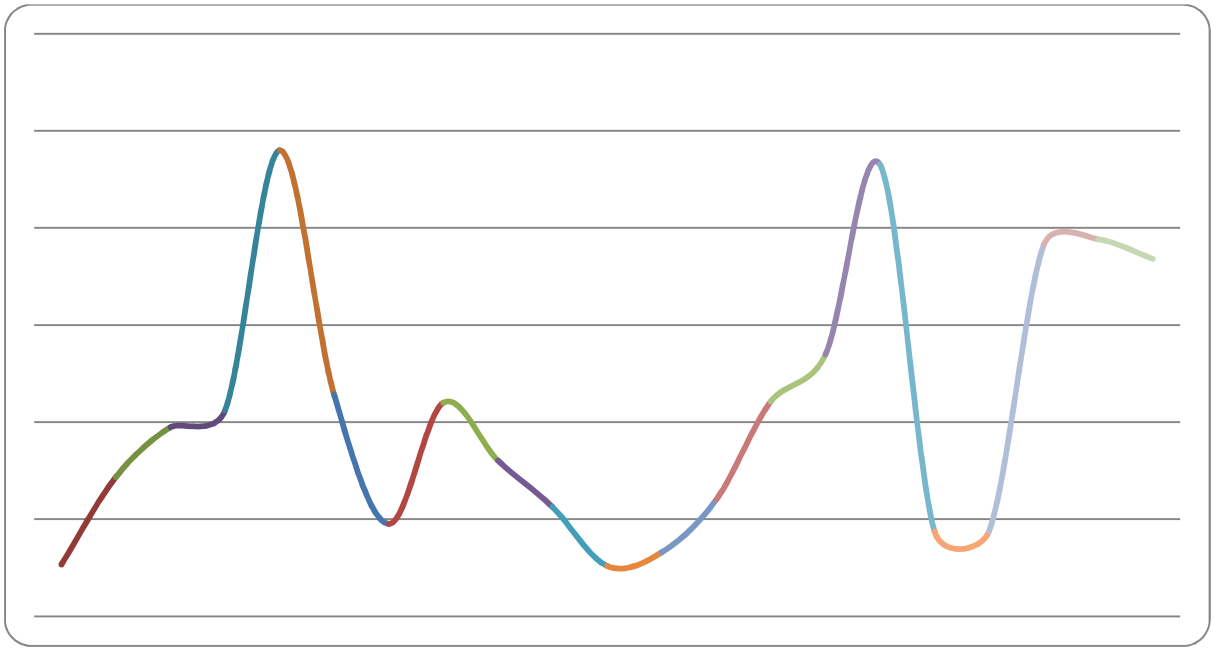

Figure 4: Progression of the ZSE Market Cap under the Various Exchange Rates

Source: MS Excel Analysis of Secondary Data

Impact of the 2003-2004 banking Crisis

The impact of the banking crisis of 2004 was not universally evident from the research findings as shown in Figure 5 below. Actuarial and insurance professionals pointed out that the banking crisis impact was rather mild, arguing that the pension funds had time to recover from the effects of the crisis and build up value as shown in figure 3 above. Since not all pension funds had money invested with the concerned banks 60% of the respondents felt it was more of an individual pension fund matter than the industry as a whole. It is however important to note that due to the relatively 'high risk' banking sector, most insurance and pension funds had to settle for the unattractive TBs compared to high yielding money market securities issued by banks.

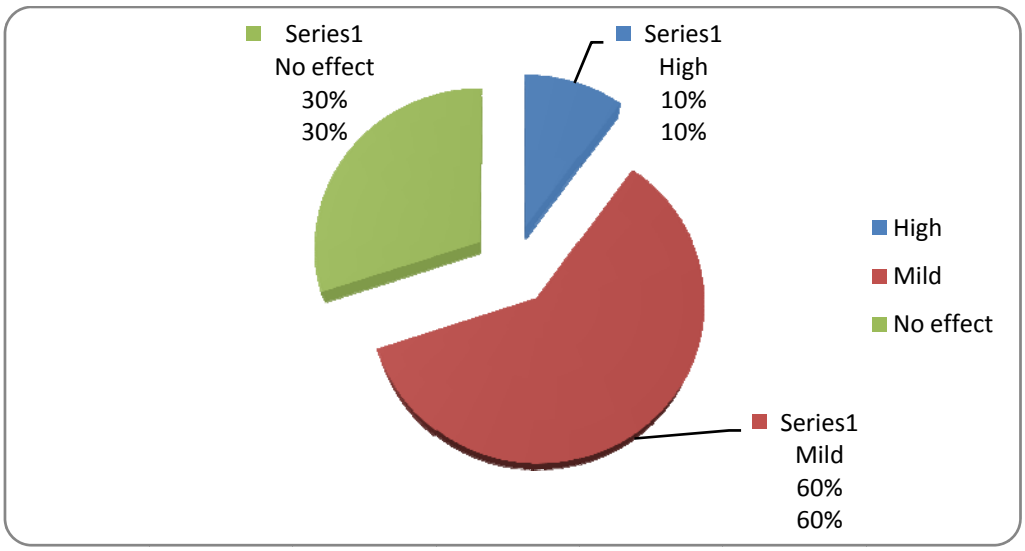

Figure 5: Impact of the 2004 banking crisis on pensions

Source: SPSS and Excel Analysis of Primary data

Failure of the pension promise and miss-selling allegations

Although the 'pension promise' seems to have failed mainly due to various factors outside the control of insurance companies/pension funds, some respondents shown in Figure 6, felt that the product seller should take some blame for the demise of their pensions. They argue insurance companies had promised to take care of their retirement and had to keep that promise. Some insurance companies continued to sell 'fixed pensions policies' while those with premium revisions still failed to perform as expected thereby raising some miss-selling allegations. Thus in line with cited authorities ([5], [6], [7], [8], [9]), Figures 1 and 6 show that insurance companies have to also share the blame with other players like the government or they should have just not given policyholders false hope 'through their continued sale of products' if the environment was 'that harsh'.

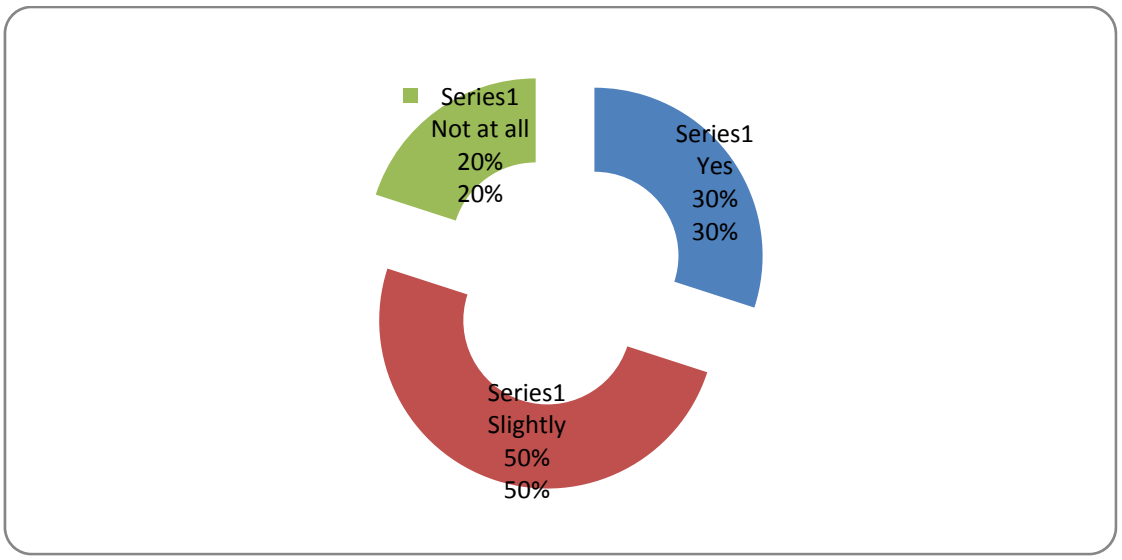

Figure 6: Insurance companies could have prevented the collapse of pensions

Source: SPSS and Excel Analysis of Primary data

CONCLUSIONS

The long term nature of pensions business makes it an inherently risky business prone to the economic changes over time. The Zimbabwean pensions industry went through a rough patch over the years 1997-2009, leading to partial/total loss of all forms of savings from ordinary savings, life assurance and pensions. From the analysis of findings; we present factors that we believe were the main causes for the demise of pensions and the subsequent failure to meet pensioner/policyholder reasonable expectations below.

Inflation has an effect of eroding value of the currency, savings in Zimbabwe dollars ceased to exist as inflation reached record figures of 231,000,000% with prices being reviewed numerous times in a single day. Inflation also led to negative real returns being experienced in the market for Government securities which made the bulk of pension fund securities. Inflation also destroyed value accumulation in both conventional fixed pensions and variable pensions as salaries lagged inflation.

The government's prescriptive high prescribed asset ratios of between (25-35%) over the period 1997-2008 became a leakage in the pension's value flow. The post dollarisation era reveals some lack of foresight on the part of insurers and regulators who instead on declaring a 'moratorium' on pension funds valuations so as to allow value recovery, led to the declaration of low property valuations (due to high void levels) as well as disposal of listed stocks owned by pension funds at huge discounts, only to have restored values 1-2 years post dollarisation.

The crisis led to loss of value of certain pension fund assets and due to the hostile business environment, some pension values did not recover from the loss. Although the OMIR did provide some form of currency conversion mechanism, it was somehow independent of local forces of supply and demand and hence the value destruction resulting from its continued use towards the end of year 2008.

Findings uncover some complex interplay between the accumulation of value and the delivery of the pension promise during hyperinflation. The researchers acknowledge that the environment was quite harsh for the insurers, but we lay a partial blame for their continued sale of product that failed to live to their anticipated PRE. The researchers therefore conclude that PRE was violated for Zimbabwean policyholders/pensioners over the period under study.

RECOMMENDATIONS

To sufficiently develop a good understanding of what really happened and to allow for normalcy to return to the pension industry, the following recommendations should be taken on board by the various stakeholders' outlines below:

We make the following recommendations to Pension funds, Trustees, Administrators and Insurance companies.

Communication

Treating customers fairly is about transparency, openness and regulatory compliance all which leads to customer satisfaction while at the same time helping to control costs associated with reputation. There is need for the insurance industry, actuarial profession and pension funds to communicate with the pensioners on the conversion process so that there is clarity and understanding of the conversion process and what happened to the pension accumulations of the past years.

Increasing Accuracy of Benefit Projections

A benefit projection tries to forecast what the future pension will be (based on a set of assumptions) when someone retires and gives an indication of what a pensioner will earn in respect of his salary. The events of post hyperinflation indicate that the actuaries failed to accurately carry out benefit projections for their pension schemes and advice on what to do. Thus pension fund communications failed to build up reasonable expectations since when one is foretold what to expect it helps shape up expectations and is well prepared in advance and is able to evaluate alternatives.

To the Government and IPEC

We propose the following measure to the government through its regulatory arm the insurance and pensions commission (IPEC).

Prescribed assets reduction

For the economies to grow prescribed assets have to be done for they are a way of social investment and a way to direct investment to the productive sectors of the economy, but this should never be at the expense of the owner of the same capital. We therefore call for competitive returns on prescribed assets as well as a prescribed asset ratio that does not work against value build up in pensioners' savings, which requires carefully designed controls and watches.

Change in regulatory framework

The researchers recommend active actuarial involvement in the work and reform of the IPEC providing input in the testing of all pension and life products before market launch in order to eliminate possible miss-selling of insurance products. The regulatory body has to move ahead in adopting some international best practice in insurance and pensions and lead the sector towards 'first world standards'.

Define PRE and outline guidelines

It is proposed that IPEC lay out guidelines on PRE that are tailored for the local market. This will be used for all insurance products and will provide a legal platform for prejudiced policyholders to be compensated.

Top up of funds

A pension is a promise to pay something meaningful when one is no longer able to provide for one self. Since value was lost and the blame has fallen more on the government legislation on prescribed assets. There is need for appreciation from the government to come up with some equitable compensatory mechanism through some form of social security to save the lives of the affected pensioners. The researchers propose that such scheme involve government, parent companies of pension funds and insurance companies who paid out pensions post USD adoption.

Active members' voluntary contributions

Value build up is an important part of pension fund management, in a normal economy, we advise working members of pension funds to build to individually top up their contributions by making 'additional' own voluntary contributions.

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Appendix I Table showing how conversion process was done.

	ZWD	USD
Assets	735,698.67	43,800.00
Liability	652,647.26	36,500.00
Funding level	113%	120%

Ref No	Accumulated credit (ZWD)	Asset share	USD Values
A001	99,497.36	15.25%	5,564.50
A002	27,312.95	4.18%	1,527.51
A003	58,607.79	8.98%	3,277.70
A004	96,467.65	14.78%	5,395.06
A005	74,185.24	11.37%	4,148.89
A006	44,497.65	6.82%	2,488.58
A007	32,693.67	5.01%	1,828.43
A008	41,391.76	6.34%	2,314.88
A009	80,456.56	12.33%	4,499.62
A010	97,536.63	14.94%	5,454.84
	652,647.26	100%	36,500.00

Source: MS Excel Spreadsheets

Psychosocial healing and reconciliation in post conflict Zimbabwe: The missing link in Zimbabwean politics.

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ABSTRACT

In this paper we argue that post-conflict recovery and reconstruction in Zimbabwe has been void of a formal psychosocial process. This translates into a continuous recurrence of dysfunctional conflicts in the history of the country. We argue that post-conflict recovery and reconstruction in Zimbabwe has been preoccupied with the infrastructure, weakened institutions and economic development components, to the neglect of mental and psychosocial aspects of recovery and reconstruction. Yet violent and destructive conflict destroys much more than buildings and roads. Those who have experienced the horrors of conflict are left traumatised. Most of the perpetrators and survivors of atrocities and rape are never taken for any mental treatment, and thus some of them deteriorate into mental cases. In this paper we argue for an integrated approach to post-conflict recovery and reconstruction that would address both hard aspects like infrastructure and economic development, and soft components like the state of the mind and relationships of post-conflict reconstruction with full participation of all stakeholders, especially the poor masses at the grassroots.

Key words: **Psychosocial, healing, reconciliation, post-conflict, dysfunctional conflicts, integrated approach, perpetrators, survivors, reconstruction**.

INTRODUCTION

We strongly believe that the major task faced by a society left in ruin after a period of unrest is the rebuilding of that society. Experience has shown that in most cases scarce resources are allocated for repairing physical infrastructure in its many forms to the exclusion of psycho-social reconstruction of the same community. Roads and bridges, for example, are given priority over issues of justice and national healing despite the fact that coming to terms with past injustices is an important foundation to sustainable peace, stability and development. Leaders fail to recognise that in order for people to come to terms with a traumatic past, a process of acknowledgement,

forgiveness, reconciliation and healing is required as stepping stones that lead to the rebuilding of a viable, health community (1). “If yesterday I fought you as an enemy, today you have become a friend and ally with the same national interest, loyalty, rights and duties as myself. If yesterday you hated me, today you cannot avoid the love that binds you to me and me to you. The wrongs of the past must now stand forgiven and forgotten.” Considering the just ended bloody war of independence and the inhuman treatment of blacks by the white colonial regime, these words by Robert Mugabe, Zimbabwe’s first post-colonial leader on 17 April 1980, a day before independence day, were a miracle and of course “a demonstration of human maturity so far rarely equalled in our world” (2). The words were full of hope, optimism and promise for a country that had been ravaged and relationships strained by war and conflict. What then went wrong? This is what we intend to answer in this paper.

Zimbabwe has witnessed several violent conflict situations including the first *chimurenga* (1896-1897), the second *chimurenga* / the liberation war (1966-1979), dissidents and the resultant *gukurahwindi* (1981-1987), the ZANU PF-MDC struggle for power (2000-present), and Operation *Murambatsvina* (Restore Order) (2006), among others. For a detailed discussion of these experiences in Zimbabwe see Raftopoulos and Savage (3), Machakanja (4), Mbire (5), Musingafi*etal* (6), among others. Although there might have been expressions of good will and desire for a healing and reconciliation process at the end of each of these destructive events as exemplified in Mugabe’s speech above, proper implementation of the psychosocial healing and reconciliation process is yet to occur. This explains the persistent recurrence of these gruesome events. The healing and reconciliation process has always been left hanging in the air.

Experience has shown that reintegration and the management of post-conflict mental and psychosocial health has been a family and private affair in post-conflict Zimbabwe. Mechanisms and strategies to deal with mental health, especially for ex-combatants and those who might have spilt blood during the violent conflict have been based on either tradition or religion. Parents and relatives have taken the ex-fighters / killers to traditional healers or prophets for cleansing and reintegration into the family and community. Most of those who were / are not taken for these rituals ended / end up becoming mental cases (see Kanengoni (7). Most of the civilian victims and survivors of atrocities, rape and abuse by the armed combatants are never taken for any mental treatment, and thus some of them deteriorate into mental cases. Thus, there were no formal mental interventions for survivors of war until the 1990s when NGOs like AMANI Trust tried to fill in the gap (8).

In 1980, Zimbabwe's experience of a long and brutal armed liberation struggle, in which two fully-fledged guerrilla armies actively engaged the Rhodesian Security Forces (RSF) against a background of mutual hostility and suspicion, called for a complex post-liberation war disarmament, demobilisation and reintegration (DDR) process. The new government, however, believed that DDR was a simple matter of demobilisation, and not a process that required a comprehensive policy that would need to be implemented for years. Their policy therefore did not deal adequately with the issue, and there was no multi-pronged approach. No attempt was made to prepare communities for the reappearance of ex-combatants, nor was there any programme aimed at resolving problems that developed in communities accepting back ex-combatants (9).

For example, after the liberation war, most ex-combatants had little formal education and few skills. Nonetheless training offered to ex-combatants was poorly planned, and was offered on a 'one size fits all' basis. Five-day courses in one skill or another were on offer every few weeks, but they did not necessarily build on the previous month's training, and there was little structured guidance as to who suited which training programme. Much of the training was irrelevant to the needs of war veterans (10). For example, many ex-combatants were trained in basic bookkeeping, but they had no businesses that needed books. Furthermore, the level of training they had was not sufficient to make them readily employable in bookkeeping in ordinary businesses. Those running the finances of co-operatives needed more than bookkeeping skills.

A General Amnesty Ordinance of 1980 was issued and it pardoned both sides of the liberation war. In 1988 a Clemency Order pardoned all violations committed by both parties between 1982 and 1987. This period marked the period of the *Gukurahwindi*. A presidential amnesty was given to the ZANU PF perpetrators of politically motivated violence during the 1990 and 1995 elections. In October 2000 the president issued an amnesty to pardon politically motivated crimes committed during the election campaign.

In all these efforts a top down approach to reconciliation was used as the general public was not consulted for specific and general issues to be addressed in the process. In 1980 for example, the need to forgive and forget was imposed on the general masses and it was not made clear to them how this was going to take place. Some action was taken by the government with regard to the *Gukurahwindi* atrocities. It set up the Chihambakwe Commission to look into the atrocities committed. It, however, proved to be a futile exercise as the report was not published. The

government did not acknowledge its guilt and no formal apology was given to the affected communities and families (11).

Generally, the reconciliation efforts made by the government proved to be rhetoric given their failure to address the fundamental issues of healing and reconciliation. In the case of politically motivated election violence the amnesties served to maintain the status quo where the perpetrators continued to enjoy immunity at the expense of the victims. These efforts also indicate that victims were not part of the reconciliation agenda as they seek to exonerate the perpetrators of their crimes (12). The fundamental elements of healing, truth telling, justice and reparations were not taken into consideration.

We therefore conclude that Zimbabwe is a nation with more than a century of unresolved conflicts. These include racism rooted in colonialism, as well as other conflicts which predated and were intentionally exacerbated by colonialism. In fact Zimbabwe is a nation with a poor tolerance for political diversity and a leadership that has been committed to never leaving power voluntarily (13). In the last forty eight years, the country has had substantially only two political leaders – Ian Smith, from 1964 until 1979, and Robert Mugabe, from 1980 until the present (2012). Both leaders have ruled the country more or less as a one-party state, and both have been embroiled in civil wars to destroy legitimate alternative political voices.

OBJECTIVES

Our aim in this paper is not only to make a theoretical contribution to the debate on persistent dysfunctional conflicts in Zimbabwe. We argue for an integrated approach to post-conflict reconstruction that would address both hard aspects like infrastructure and economic development, and soft components like the state of the mind and relationships of post-conflict reconstruction with full participation of all stakeholders, especially the poor masses in the affected communities. One major purpose of this paper is to conscientise policy-makers on the need for mental healing, reconciliation and community reintegration processes that involve both survivors and perpetrators. We argue that people at the grassroots are the most affected and therefore they are the pillars of post conflict recovery and reconstruction processes. Their involvement is of paramount importance. We argue for a conceptual framework for grassroots involvement in post-conflict psychological and social reconstruction. This approach, we believe, will fill in the gap that has remained persistent in Zimbabwean political history and thus bring in a lasting process of national healing and reconciliation

METHODOLOGY

Research methodology is about the approaches and techniques used in administering a research study. A research study is designed and conducted to gather data that would be turned into information that helps in solving a community problem. In this case the problem is recurring dysfunctional conflict in Zimbabwe due to weak post-conflict healing and reconciliation processes. Jackson (14), Whitmore (15), and Cornwall and Jewkes (16) argue that community studies should be carried out with the people being studied rather than on them. Jackson further argues that such participatory approaches benefit the community studied rather than just the researchers and policy makers. The value of studies lies in the changes they bring to communities rather than simply in the knowledge gained

In this paper we thus take note of the above authors' observations. Although the paper is largely a survey of theoretical and empirical literature, we back it with some informal group discussions with fellow staff members and workmates at the Zimbabwe Open University (ZOU) Masvingo regional campus. In fact, most of the ideas in this paper are a built up from these discussions, especially after the advent of the current Government of National Unity. Thus, the methodology used in this paper is largely qualitative research based on documentary analysis and informal group discussions coupled with the authors' intimate knowledge of Zimbabwean, especially post-colonial Zimbabwe history based on both academic literature, and peripheral-experiential participant observation.

FINDINGS

In this section we discuss and synthesize findings from the three different data sources for this paper, namely findings from literature, informal discussions, and experiential participant observation.

Overview

First and foremost, our literature survey established that the pre-colonial era, the colonial era, and the post-colonial era serve as identifiable historical periods in which Zimbabwean conflicts have taken place. Each era has its own sources of conflict that can be seen as political, economic, and cultural. The different eras have deeply influenced each other. Conflicts that existed before colonialism were used by the colonial system's divide and rule strategies for the purposes of maintaining power and control, only to have some of the same modes of thinking, strategies and institutions inherited and perpetuated in the post-colonial period. This makes the challenges of

healing, reconciliation, justice and peace in Zimbabwe very complex as it becomes necessary to deal with the present hurts and wounds as well as trace the wounds of the past (17). Historical wounds have been carried to the present through memories, oral traditions and recorded reports. Members of one group that was victim to violence in one era have sometimes turned out to be the perpetrators in another.

Secondly, we found out that pre-colonial ethnic conflicts over control of resources and demarcation of territories are deep sources of conflict in our history. For example the Ndebele raids on some Shona groups have left painful wounds among the Shona. The Shona have passed on to their children stories about the raids which involved the confiscation of cattle, food, strong young men and beautiful women by the Ndebele. The Shona have, over the years, cultivated negative feelings towards Ndebele groups. These feelings include hatred, contempt, suspicion and the desire to retaliate. These feelings explain the continued rivalry of the groups that has been shown during the liberation struggles and in sport, cultural and political activities. We therefore need to heal hurtful memories from this ethnic rivalry.

Thirdly, we established that the colonial era *w*as characterised by racial conflicts stemming from racial discrimination. Inferiority complexes developed among the blacks and superiority complexes developed among the whites. This created resentment among the blacks who then waged liberation struggles. These struggles further triggered hatred between the racial groups. These perceptions and feelings still do affect us today. We need healing from them. But before that can be achieved, racial groups need to repent of their respective sins.

We also found that although the post colonial era came with the joy of independence, expansion in education, health care and social services; as a nation, we made mistakes. We forgot to attend to the needs of those who were traumatised by the war especially the ex-combatants. We ignored those who were physically and psychologically devastated by poverty, discrimination and oppression. They all were neither counseled nor treated. Whites who lost political power were not helped to heal from the trauma of that loss. We all pretended that we could start afresh in a new Zimbabwe without dealing with our past or defining collectively what future we desired for our nation. We pretended that the anger and hatred that had accumulated over many years could simply vanish with independence. This failure to deal with our past continues to haunt us.

Amnesia and impunity

We established that amnesia was included as a constituent element in the Lancaster House Agreement (18). By amnesia we mean an officially imposed form of forgetting. It was argued that silence about the past was what Zimbabwe needed. Searching for the truth would constantly reopen old wounds and damage the politics of reconciliation. This strategy drew a veil over the human rights violations of the Rhodesian secret service, army and police. It was, also, appreciated by the leaders of the liberation movements because it meant closing the books on their violence against civilians and their rivals in the training camps.

Nevertheless, information about the colonial and liberation war atrocities was not completely lacking. Domestic NGOs such as the Justice and peace Commission (CPC) in Rhodesia (now the Catholic Commission for Justice and Peace). and the Catholic Institute for International Relations have documented torture, resettlement and eviction in the 1970s. Amnesty International has published reports on war crimes in Rhodesia. Women members of the liberation movements have spoken out about sexual assaults by their male companions in the camps. But any official acknowledgement of the horrors of the past has consistently failed to materialise. Amnesia has its institutional expression in legal immunity and amnesty. It thrived in both Rhodesia and Zimbabwe, and the consequence is a culture of impunity.

The pattern of impunity in pre-independence Rhodesia and post-colonial Zimbabwe consists of many elements: erosion of the independence of the judiciary; political manipulation of the police; and silencing independent media and human rights organisations. But by far the most forceful instrument is the recurrent use of indemnities, amnesties and pardons. Granting an amnesty to the Rhodesian police and military personnel for human rights violations was a tradition long before the liberation war was at its height and the Indemnity and Compensation Act of 1975 sanctioned this tradition. The Act was repealed, butthe political utility of immunity was underlined and surfaced in the form of the repeated use of the executive's power of pardon and ad hoc clemency orders. Furthermore, the ZANU-PF government also retained, and has reinforced, most elements of the previous state of emergency (giving it, among others, the power to detain without trial).

Reconciliation imposed from above

The various parties in the negotiations that led to Zimbabwe's independence imposed the politics of reconciliation on the black population. It was a project conceived and developed at the level of the elite. There was no society-wide debate or involvement. Victims and survivors were not consulted,

but rather watched powerlessly as many perpetrators of human rights violations went unpunished and even took on key roles within the Zimbabwean Army and secret services. As a consequence the need to forgive and forget was not internalised by the general public.

Survivors of the war of liberation

In the late 1990s the AMANI rehabilitation project in Mount Darwin established that the survivors of the 1970s war still had little education, high unemployment, and very few work related skills. They mainly survived on subsistence agriculture, and were thus very susceptible to the vagaries of the weather. Food security and employment were the major reported problems and usually the focus of all clinical conversations. Less than 1% of the survivors had access to piped water. Most of them (98%) still cooked using increasingly scarce firewood, and more than 30% did not have access to a toilet of any kind. Infant mortality was high, and the medical facilities were meagre and increasingly stretched: 2 hospitals and 11 clinics for 200,000 people. These facilities were focused mainly upon curative care, especially with the burden of an HIV epidemic. More than 30% of clinic and outpatient clients were those suffering from psychological disorders. One in ten of the total adult morbidity was a victim of organised violence and torture. Reeler reports that the AMANI's approach has been to develop a holistic model for rehabilitation, one in which the needs of the entire community are taken into account, and one in which conventional rehabilitation will stand in partnership with community development.

Pursuit for power

We established that some groups and individuals in our communities have shown the desire to monopolise power and political control at the expense of other groups and individuals. Those who have been marginalised have resisted the exclusion. The resultant conflicts have formed the basis of the political conflicts that have arisen among us and the contexts within which we have done wrong against each other. Our political history is characterised by the use of state institutions as partisan tools. Those who have opposed the ruling party have been marginalised and sometimes criminalised. In our history, there has not been space created to allow for healthy political debates and contestation. This has caused a lot of frustration and resentment. The formation of strong political opposition parties has become a source of strong political conflicts and violence. Women, the youth and minorities feel that they are not fully included in the development of the country. So, politically, our country is deeply divided and in great need of psychosocial healing and reconciliation.

Economic issues

Economic sources of conflict are to do with control of the country's resources including wealth, land, minerals, property and other national resources. Poverty of the marginalised majority, corruption, mismanagement of resources, sanctions, lack of transparency and accountability are continuing sources of conflict. In fighting for our undermined dignity and in defending our economic advantages, we have lost sight of the humanity of others. We have been divided by disagreements on how national resources and social goods are to be owned, used and distributed. At the centre of economic conflicts has been the distribution and re-distribution of land. The post independence economic downturn that was partly caused by the experimentation with structural adjustment programmes and the crisis of leadership that has continued to dog our country led to frustration. This frustration and impatience eventually led people to resort to using violent and non-transparent means of accessing the land. Corruption, incompetence, mismanagement, arrogance, and economic greed led to the collapse of our economy. With high inflation, unemployment and poverty many fled to the diaspora where they continue to experience economic hardships.

The Government of National Unity (GNU)

The signing of the Global Political Agreement (GPA) (2008) (with a clause on national healing and reconciliation) presented an opportunity for a new inclusive government and consideration of issues of national healing. It came at an opportune time to end a political stalemate that had resulted in the degeneration of a sense of humanity among people manifesting in the form of violence. The provisions on national healing and reconciliation (Article 7) ushered in a new step for further discussions and mapping of reconciliation efforts in Zimbabwe to seek redress for violent conflicts that had happened in Zimbabwe's history. The Organ on National Healing, Reconciliation and Integration (ONHRI) was thus established in accordance to Article 7 of the GPA to lead national healing and reconciliation processes. The creation of ONHRI provided a new frame through which the discourses of reconciliation and national healing can be implemented. Since 2000 Zimbabwe has experienced a plethora of violent incidents. These violent incidents reached their peak in 2008 thus necessitating a mechanism for reconciliation and healing. People continue to harbour feelings of hurt that need to be addressed through a national structure such as ONHRI. It is however important to note that although ONHRI has done some work it still falls far from achieving its mission. ONHRI is crippled by numerous challenges; among them being an inadequate policy framework, political obstacles, and implementation challenges within government structures (19).

CONCLUSION

As observed by the Zimbabwe Catholic Bishops' Conference (20) the foregoing shows that we, Zimbabweans, have hurt each other in many different ways and over long periods of time. We are all guilty, for those who have been victims at one time have been aggressors at another and many more have done nothing in the face of atrocities perpetrated before their eyes. We therefore need healing from these hurts and from our guilt. This healing will facilitate reconciliation within and among ourselves. With healing and reconciliation, our nation will recover and set itself up for political, social, cultural and economic development.

In fact, unlike Rwanda that has accepted and owned its past experiences thereby agreeing to a psychosocial and mental healing process as illustrated in the *gacaca* initiatives (21), Zimbabwe is yet to acknowledge and practically own its past experiences.

RECOMMENDATIONS

Overally we recommend an integrated and holistic approach that would merge the hard and soft components of post conflict recovery and reconstruction. For national reconciliation and healing to take place effectively, the entire nation should participate in a comprehensive, all-inclusive, holistic and clearly defined national healing process underpinned by strong political will and desire to reconcile and heal the nation. We envision national healing and reconciliation as a home grown inclusive process that will lay the foundations for a peaceful and cohesive Zimbabwean society; where the security of individuals and communities is guaranteed; where the dignity of the individual is respected; where broken relationships are mended; where trust is restored; and where diversity is celebrated.

Reconciliation has to be based on more than rhetoric. We thus recommend commitment and implementation of policy. We must walk the talk as action speaks better than words. Also a simple public acknowledgement of what went wrong in the past, a minimum of retribution and redress and, above all, progress towards economic justice are needed. These crucial factors were not sufficiently developed in post colonial Zimbabwe as already shown above.

We also strongly believe that a successful national healing and reconciliation process requires meaningful engagement of civil society and the public at large. This is because a process aimed at responding to people's needs must necessarily involve the people affected by the conflict,

especially at grassroots level. Civil society is thus well positioned to mobilise people to fully participate in the national psychosocial healing and reconciliation programmes and processes.
There is a need to educate the general Zimbabwean community about the experiences of trauma and grief as well as their extent and effect on women, men, children, the elderly and the disabled. There is also a need for re-education on how communities that have experienced violent conflicts can coexist in peace and harmony. Educational programmes should be linked to processes of trauma-healing and reconciliation and should be acknowledged by the wider community, as affirmation of a public commitment to the broader healing process agenda.

The availability of counselling services to help people in post-conflict situations deal with their experiences of trauma and grief as well as specific counselling to do with particular situations is important. Counselling formats would need to be specifically developed in holistic and culturally appropriate ways to deal with longstanding, past or profound traumatic experiences. Other useful indigenous initiatives include narrative therapy and family therapy in which affected people tell their stories about the violence and its consequences on themselves and family members (as in the *gacaca*case in Rwanda). As part of indigenous reconciliation dialogues, these processes will help the younger generation understand what their parents and grandparents lived through as well as assist in the rebuilding of fractured societal relationships.

We further recommend special healing places and community intervention programmes. We believe that there could be value in the development of special places of healing such as trauma healing centres and special nature parks where people can visit as part of the relaxation and therapeutic process. We propose that people could visit and stay at such recreational places as part of the healing process. These recreational healing places could be developed with supportive programmes where people undertake community-based, skills-orientated training programmes relevant to the development of their communities. Such promotional projects would strengthen sustainable peace by furthering social investment and the unification of the social fabric of society. Thus, peace through community reconciliation, engagement and empowerment can yield powerful results.

Lastly we recommend memorialisation and ritualisation. Taking cognisance of the cultural context of the African setting, memorialisation of the past is important. This would require physical reminders in the form of monuments, ceremonies, memorials or other ritual occasions aimed at contributing to the acknowledgement as well as the setting of a general ethos of healing. Museums

at the local level can further the objectives of the state with respect to creating a historical narrative and furthering national identity. Local museums can also be used as sites for community gathering, commemoration, cultural celebrations as well as educational activities for the younger generation. The effectiveness of memorialisation processes may further be enhanced through regional and international networks which support local activities.

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