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FACULTY OF SCIENCE

DEPARTMENT OF GEOGRAPHY

THE USE OF GEOGRAPHICAL TECHNOLOGIES IN LAND COVER CHANGE DETECTION AND MANAGEMENT IN MUZARABANI DISTRICT.

By

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY (FACULTY OF SCIENCE), IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF A BACHELOR OF SCIENCE HONOURS DEGREE IN DEVELOPMENT STUDIES

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DECLARATION

I hereby declare that this research project has been a result of my own original efforts and investigations and such work has not been presented elsewhere for the purpose of the degree assessment. All additional sources of information have been acknowledged by means of references.

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APPROVAL AND RELEASE FORM

The undersigned certify he has read the research project and has approved its submission for marking after confirming that it conforms to the departmental requirements.

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…………………………………………..   …………………………………….

Signature   Date

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DEDICATION

To Prestige…….

…………….you came at the crucial moment.

ABSTRACT

This study investigated environmental change over a twenty eight-year period and attempted to gain a better understanding of human impacts on land cover and consequences. The research also sought to use GIS and RS technologies to detect changes brought about by human-environment interactions and calculate the rate of change, thereby coming up with a land cover change map. The methodology used was mainly based on image differencing of satellite images that were acquired for the years 1986, 1998 and 2014. Multitemporal remotely sensed imagery was acquired and integrated to establish the basis for change detection and process analysis. ENVI 4.7 image processing software was used coupled with Q-GIS 2.8.1-Wien to produce land cover and land cover change maps. Land cover changes were investigated in two categories, namely categorical change using image classification and quantitative change using image differencing. The results show that human-induced land cover changes have been minor in this remote district though sudden changes are seen after the introduction of the FTLSP. The rate of land cover change was there found to be relatively small. In addition, the pace of growth of human-induced change has been accelerating since the early 1990s. The results suggest that the current trend of rapid growth may not be sustainable and that the implementation of effective counter-measures for environmentally sound development is a rather urgent matter especially building on the works of environmental institutions like EMA. Some of the regulations proffered include the finalisation of the land program in terms of ownership, broad based environmental education and conservation practices. The adoption of GIS and RS related tools in change detection and management is strongly emphasized.

Key words: Land use, land cover, change detection, GIS, remote sensing

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List of Acronyms and Abbreviations

CCRS	-	Canadian Centre for Remote Sensing
CV/CVA	-	Change Vector/ Change Vector Analysis
ENVI	-	Exelis Visual Information Solutions
ERDAS	-	Earth Resources Data Analysis System (ERDAS)
EMA	-	Environmental Management Agency
ESRI GIS	-	Environmental Systems Research Institute GIS
FAO	-	Food and Agricultural Organisation
GIS	-	Geographic Information System
LULC	-	Land Use and Land Cover
Q-GIS	-	Quantum GIS (version 2.8.1-Wien)
RS	-	Remote Sensing
RDC	-	Rural District Council
PCC	-	post classification comparison
ZIMSTAT	-	Zimbabwe National Statistics Agency

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Table 5.1: Muzarabani Population Distribution by Ward, Sex and Household

CHAPTER 1 : RESEARCH INTRODUCTION

1.1 Introduction

The advent of computer technology has brought a new dimension to the field of geography. Man's presence on planet earth has had a profound impact on the natural environment with the situation being compounded by a rapid increase in population and the expansion into marginal lands. Geographic Information Systems (GIS) and Remote Sensing (RS), which started as military applications, are now being applied for the general benefit of mankind (Rolf, 2001). Whilst it cannot be disputed that GIS and RS are now providing new tools for advanced ecosystems management, most developing nations have been lagging behind and as such still face a host of challenges in management of land use changes. Kervyn (1995) noted that modelling of topography will become an easy task once land use cover changes have been noted and proper and informed decision making can be made.

Change detection often involves comparing aerial photographs or satellite imagery of the area taken at different times (Petit, 2001). The process is most frequently associated with environmental monitoring, natural resource management, or measuring urban development to mention but a few. Understanding landscape patterns, changes and interactions between human activities and natural phenomenon are essential for proper land management and decision improvement (Prakasam, 2010). Land use and land cover (LULC) change detection is very essential for better understanding of landscape dynamics during a known period of time thus facilitating the prospects of change management in a sustainable manner. LULC change has been recognized as an important driver of environmental change on all spatial and temporal scales (Rawat, 2013), as well as emerging as a key environmental issue & on a regional scale is one of the major research endeavours in global change studies.

Changes may involve the nature or intensity of change but may also include spatial (forest abatement at village level, or for a large-scale agro industrial plant), and temporal aspects. LULC changes also involve the modification, either direct or indirect, of natural habitats and their impact on the ecology of the area (Rogan, 2004). RS technology for capturing the spatial data, GIS for undertaking integrated analysis, presentation of spatial and associated attribute data are found to be much more effective to determine and manage the change detection of LULC (Lillesand and Kiefer, 1999).

Muzarabani District is endowed with wide variety of land cover types having the capability of supporting and enhancing biological diversity. Infrastructural development from urban expansion, extraction of forest products to meet fuel needs and other social demands and agriculture are the chief causes of the rapid decline of physical environment. As a survival strategy, man has decided to expand agricultural practice into other pieces of land, especially those that are marginal or into forests. These causes of land cover change has neccesiated the need for adequate information from which appropriate resources management strategy and interventions can be derived. The process of policy formuation in Zimbabwe has been based on reactionalistic tendencies (Zhou and Zvoushe, 2012) and as such the need to capture the value of GIS and RS so as to enhance solid environmental and social policy fomulation. The ability to combine and intergrate data using a set of analytical function is the backbone of a GIS. This enables changes to be monitored, mapped and analysed in a timely and cost effective manner.

Faced with a challenge to reverse the imbalance of the land ownership in Zimbabwe, the Government of Zimbabwe embarked on a Fast Track Land Reform Programme in 1999/2000 (Sachikonye, 2002). As such, occupations occurred with settlers clearing large tracks of land for agricultural purposes. The impacts of these land occupations have not been fully documented in terms of quantities except as case studies (Sachikonye, 2002; Rukuni and Eicher, 2001). It therefore is imperative that an attempt be made, within the context of this study, to map out the status of LULC for the period under review. Bias will be made towards the natural environment so that future land use modelling can be developed and used to manage this development challenge for Zimbabwe.

1.2 Statement of the Problem

Global environmental problems know no boundaries and as such local land use and vegetation cover change has a significant and direct cumulative impact. This is so because loss of land and land use change may imply loss of biological diversity with the end result being that some fauna and flora will become extinct. Land scarcity and the general increase in population has forced most if not all farming families to expand their cropping and grazing lands into natural forests. Some of these ventures are not sanctioned by experts and as such a vicious circle of poverty, land degradation and declining harvest set in. In developing nations, especially in Africa, GIS and RS have not been fully applied especially in marginal and hazard prone areas to effectively detect changes in land cover and its management. Furthermore, local land cover change has significant and cumulative impact on regional and global climate changes.

1.3 Justification

Land use and land cover change has become a central component especially in the current strategies for management of natural and man-made resources. Attempts have been made in the past to document LULC change using aerial photographs. The high rates of mechanisation in effecting changes in LULC now require more powerful and sophisticated systems such as GIS and RS. Various studies that have been done show that there remains only few landscapes on earth that are still in their natural state (Daniel, 2002; Manzungu and Mtali, 2012; Burrough and McDonnell, 1998; Dimyati, 1995). The current understanding of historic LULC change in Zimbabwe is not adequate especially for districts that are disaster prone like Binga, Chiredzi and Muzarabani among others. There is need to greatly improve the systematic methods and designs addressing land use change research thus culminating into increased understanding of LULC change. It is necessary to conduct studies that clearly show the variations in change characteristics. This research also addresses relevant issues on land cover changes in relation to the socio-economy and provides statistical information that may help in supporting assumptions on LULC and help in attainment of sustainable development goals (SDGs).

The data will also be used to develop information on land cover changes, rate of cover change and also provide a pictorial view of the nature of change since change detection maps will be produced. Muzarabani District was selected because of its uniqueness in terms of ecological diversity and proneness to natural floods both induced by rains and opening of floodgates at Kariba Dam along the mighty Zambezi River. In addition, floods are caused by the accumulation of water with rivers failing to drain away water in Cahora Bassa Dam. It is one of the districts in Mashonaland Central in particular and in Zimbabwe in general to have the highest incidence in flood occurrences.

1.4 Aim

The main aim of carrying out this research is to assess the changes in land cover in Muzarabani District focusing on the period 1990 to 2014.

1.5 Specific Objectives

1) To detect the changes in land cover.

2) To produce a land cover change map.
3) To calculate the rate of land cover change.
4) To calculate the land consumption rate over the period under review.

1.6 Research Question

What has been the nature of land cover change in Muzarabani District?

Specific Research Questions

1) Has changed occurred in the study area?
2) What is the nature of the land cover map?
3) What is then rate of land cover change?
4) What is the land consumption rate over the period under review?

1.7 Delimitation of the Study

The study is confined to Muzarabani District and this area provides a good array of how GIS and RS can be used to not only detect changes but also to manage the change.

1.8 Definition of Terms

Change Detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989).

GIS (geographic information systems) is a computer assisted system for the acquisition, storage, analysis and display of geographic data (Rolf, 2001).

Land cover: Implies the physical or natural state of the Earth's surface

Land use is the manner in which human beings employ the land and its resources. It can be defined more broadly to include the social and economic purposes and contexts for and within which lands are managed or left unmanaged such as subsistence versus commercial, rented versus owned, private versus public land (Ellis, 2012; FAO, 2010)

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with object, area, or phenomenon under investigation (Buckey, 2011).

1.9 Organisation of the Study

The study is organised into five chapters. Chapter one provides the overall structure and introduces the research study. It is comprised of background of the study, research aims and objectives, research questions and definition of key terms among other issues. Chapter two focuses on the related literature. A global, regional and local perspective and studies related to LULC are looked at. In Chapter three, a description of the study area is given including physiographic and climatic issues. The design of the study and methods used are discussed. Chapter four presents the findings of the research with a discussion on the analysis of the results. The data is presented in various formats. Chapter five provides the conclusion and recommendations. A reference list and appendices of all materials used are also included.

1.10 Chapter Summary

The chapter provided the introductory part of the study giving a background and justification. The general and specific aims are outlined including the research questions and a layout of the organisation of the study.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

Considerable research has been done to determine the changes that have been brought about by the interaction between mankind and his environment. According to Jensen (1996) every parcel of land on the Earth's surface is unique in the cover it possesses. LULC are distinct yet closely linked characteristics of the Earth's surface. The use to which land is put could be grazing, cropping, water harvesting, urbanization (housing, industrial activity, recreational), forestry and mining among many others. On the other hand, land cover categories could be grassland, cropland, forest, wetland, pasture, roads and or urban, just to mention but a few. The term land cover originally referred to the kind and state of vegetation, such as forest or grass cover but it has broadened in subsequent usage to include other things such as human structures, soil type, biodiversity, surface and ground water (Buckey, 2011).

2.2 Development of Change Detection over Time

Change detection is the process of identifying differences in the state of an object or phenomena by observing it at different times (Singh, 1989). Daniel (2002) defines it simply as a process of noting changes of features over space and time. Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Four aspects of change detection which are important when monitoring natural resources and other important changes have been provided (Story and Congalton, 1986; Cracknell and Hayes, 1991). These are detecting the changes that have occurred, identifying the nature of the change, measuring the area extent of the change, and assessing the spatial pattern of the change. Change detection is therefore spatial and temporal in approach.

Change detection history starts with the history of remote sensing and especially the first aerial photograph taken in 1859 by Gaspard F. Tournachon, also known as Nadar (Théau, 2013). Thereafter, the development of change detection is closely associated with military technology during the first and second World Wars and the strategic advantage provided by temporal information acquired by remote sensing (Singh, 1989; Short, 2004). Civilian applications of change detection were developed following these events in the 20th century using mostly interpretation and analogue means. However, civilian availability of data was limited until the 1970s and 1980s due to military classification of imagery (Théau, 2013).

The development of digital change detection era really started with the launch of Landsat-1 (called first: Earth Resources Technology Satellite) in July 1972 (Théau, 2013). The regular acquisition of digital data of the Earth surface in multispectral bands allowed scientists to get relatively consistent data over time and to characterize changes over relatively large area for the first time. The continuity of this mission as well as the launch of numerous other ones ensured the development of change detection techniques from that time. However, the development of digital change detection techniques was limited by data processing technology capacities and followed closely the development of computer technologies. The situation evolves from the 1960s when a few places in the world were equipped with expensive computers to the present when personal computers are fast and cheap enough to apply even complex algorithms and change detection techniques to satellite imagery (Théau, 2013; Cihlar, 2000). The computer technology also evolved from dedicated hardware to relatively user friendly software specialized for image processing and change detection.

Based on published literature, the algebra techniques such as image differencing or image ratioing were the first techniques used to characterize changes in digital imagery during the 1970s (Cracknell and Hayes, 1991; Singh, 1989; Théau, 2013) . These techniques are simple and fast to perform and are still widely used today. More complex techniques were developed since then with the improvement of processing capacities but also with the development of new theoretical approaches. Change detection analysis of the Earth surface is a very active topic due to the concerns about consequences of global and local changes. This field of expertise is thus constantly progressing.

2.3 The Interactions of LULC

Land use affects land cover. A change in either however, is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply degradation of the land. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biological diversity, water and heat budgets, trace gas emissions and other processes which ultimately come together to affect climate and the biosphere (Mas, 1999; Ellis, 2012; Manzungu and Mtali, 2012). Land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover (Cracknell and Hayes, 1991). Globally, land cover today is altered principally by direct human use with activities such as agriculture and livestock raising, forest harvesting and management and urban and suburban construction and development.

There are also incidental impacts on land cover from other human activities such as forest and lakes damaged by acid rain caused by burning of fossil fuels, exhaust fumes from cars with crops near cities damaged by effects of these (Short, 2004). Hence, in order to use land optimally, it is not only necessary to have the information on existing LULC but also the capability to monitor the dynamics of land use resulting out of both changing demands of increasing population and forces of nature acting to shape the landscape. This study will also be crucial in availing information to fill this gap.

The conventional ground methods of land use mapping are not only labour intensive and time consuming, but are also done relatively infrequently. These maps soon become outdated with the passage of time, particularly in a rapid changing environment. In fact, according to Rolf (2001), monitoring changes and time series analysis is quite difficult with traditional method of surveying. In recent years, satellite remote sensing techniques have been developed, which have proved to be of immense value for preparing accurate LULC maps and monitoring changes at regular intervals of time (Adeniyi and Omojola, 1999; Elwood, 2006; Ellis, 2012). Effectiveness of RS is enhanced when married with GIS since RS act as a data source for GIS. In case of inaccessible areas and regions, this technique is perhaps the only method of obtaining the required data on a cost and time-effective basis.

A remote sensing device records response which is based on many characteristics of the land surface, including natural and artificial cover. It basically uses the reflective capacity of phenomena that have different signatures (Cracknell and Hayes, 1991). An interpreter uses the element of tone, texture, pattern, shape, size, shadow, site and association to derive information about land cover (Mas, 1999). Unfortunately, the generation of remotely sensed data/images by various types of sensor flown aboard different platforms at varying heights above the terrain and at different times of the day and the year does not lead to a simple classification system. It is often believed that no single classification could be used with all types of imagery and all scales (Mas, 1999; Short, 2004; Story and Congalton, 1986). To date, the most successful attempt in developing a general purpose classification scheme compatible with remote sensing data has been by Anderson *et al*, (1976), which is also referred to as USGS classification scheme. Other classification schemes available for use with remotely sensed data are basically modification of the above classification scheme.

Ever since the launch of the first remote sensing satellite (Landsat-1) in 1972, LULC studies were carried out on different scales for different users. For instance, waste land mapping of India was carried out on 1:1 million scales by NRSA using 1980-82 Landsat multi spectral scanner data. About 16.2% of waste lands were estimated based on the study (Pandy and Nathawat, 2006). It has been noted that information about change is necessary for updating land cover maps and the management of natural resources (Cracknell and Hayes, 1991; ERDAS Field Guide, 1999; Mas, 1999). The information may be obtained by visiting sites on the ground and or extracting it from remotely sensed data. When stored in a GIS, it is an easy task to determine and track the changes that are occurring thus proffering appropriate policy response mechanisms.

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed (Cracknell and Hayes, 1991). Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power. A wide variety of digital change detection techniques have been developed over the last two decades. Eleven different change detection algorithms were found to be documented in the literature by 1995 (Daniel, 2002; CCRS, 2004; ERDAS Field Guide, 1999). Some of these included mono-temporal change delineation; delta or post classification comparisons; image differencing and image ratioing among others. Some of the methods are discussed below under section 2.8 on change detection methods.

2.4 Estimates on LULC

In some instances, LULC may result in environmental, social and economic impacts of greater damage than benefit to the area (Daniel, 2002; Short, 2004). Therefore, data on land use change are of great importance to planners in monitoring the consequences of land use change on the area. Such data are of value to resources management and agencies that plan and assess land use patterns and in modelling and predicting future changes. Cihlar (2000) investigated the advantages of remote sensing techniques in relation to field surveys in providing a regional description of vegetation cover. The results of the research were used to produce four vegetation cover maps that provided new information on spatial and temporal distributions of vegetation and allowed regional quantitative assessment of the vegetation cover.

Pandy and Nathawat (2006) carried out a study on LULC mapping of Panchkula, Ambala and Yamunanger Districts, Hangana State in India. They observed that the heterogeneous climate and physiographic conditions in these districts has resulted in the development of different land use land cover in these districts, an evaluation by digital analysis of satellite data indicated that majority of areas in these districts were used for agricultural purpose (Pandy and Nathawat, 2006). The hilly regions exhibited fair development of reserved forests. It is inferred that LULC pattern in the area was generally controlled by agro-climatic conditions, ground water potential and a host of other factors.

It has been noted over time through series of studies that Landsat Thematic Mapper is adequate for general extensive synoptic coverage of large areas (ERDAS Field Guide, 1999; Daniel, 2002; Pandy and Nathawat, 2006). As a result, this reduces the need for expensive and time consuming ground surveys conducted for validation of data. Generally, satellite imagery is able to provide more frequent data collection on a regular basis unlike aerial photographs which although may provide more geometrically accurate maps, is limited in respect to its extent of coverage and in cost terms (Cracknell and Hayes, 1991). It therefore means that it is not often used. These views therefore pose variations that can be adopted when remote sensing is considered as a data source in any GIS system.

In 1985, the U.S Geological Survey carried out a research program to produce 1:250,000 scale land cover maps for Alaska using Landsat MSS data (Fitz-Patrick, 1987). The State of Maryland Health Resources Planning Commission also used Landsat TM data to create a land cover data set for inclusion in their Maryland Geographic Information (MAGI) database. All seven TM bands were used to produce a 21-class land cover map (EOSAT, 1994). Also, in 1992, the Georgia Department of Natural Resources completed mapping the entire State of Georgia to identify and quantify wetlands and other land cover types using Landsat TM data (ERDAS Field Guide, 1999). The State of southern Carolina Lands Resources Conservation Commission developed a detailed land cover map composed of 19 classes from TM data (EOSAT, 1994). This mapping effort employed multi-temporal imagery as well as multi-spectral data during classification. These various project just go to point to the increasing importance of use of geographical technologies in better management of resources.

An analysis of LULC changes using the combination of MSS Landsat and land use map of Indonesia reveals that LULC were evaluated by using remote sensing to calculate the index of changes which was done by the superimposition of LULC images of 1972, 1984 and land use maps of 1990 (Dimyati, 1995). This was done to analyze the pattern of change in the area, which was rather difficult with the traditional method of surveying as noted by Adeniyi and Omojola (1999) when they were aerial photographic approach to monitor urban land use in developing countries, with Ilorin in Nigeria as the case study.

In his comparison of LULC detection methods, Daniel (2002) made use of five methods that are traditional post-classification cross tabulation, cross correlation analysis, neural networks, knowledge-based expert systems, and image segmentation and object-oriented classification. Nine LULC classes were selected for analysis. The researcher observed that there are merits to each of the five methods examined, and that, at the point of the research, no single approach can solve the land use and land cover change detection problem.

In addition, Adeniyi and Omojola (1999) in their land use land cover change evaluation in Sokoto-Rima Basin of North-Western Nigeria based on Archival Remote Sensing and GIS techniques, used aerial photographs, Landsat MSS, SPOT XS/Panchromatic image Transparency and Topographic map sheets to study changes in the two dams, Sokoto and Guronyo between 1962 and 1986. The work revealed that LULC of both areas was unchanged before the construction while settlement alone covered most parts of the area. However, during the post-dam era, LULC classes changed but with settlement still remaining the largest.

2.5 Regional and Local LULC Changes

Africa houses plentiful economic resources. Paradoxically, the continent still languishes in abject poverty, famine and hunger. Since the practice of shifting cultivation and nomadic pastoralism is on the decline in Africa (Waugh, 2010), not much meaningful studies have been done to determine the extent, nature and type of change that has occurred. Most of the studies that have be done in relation to change detection and management for developing nations has been as case studies mainly for countries like Nigeria, India, South Africa, Egypt and Tunisia (Adeniyi and Omojola, 1999; Pandy and Nathawat, 2006). The reason that may be given is because of the advances these economies have made especially in information and communication technologies. The greatest rates of change have been noted in forestry especially due to deforestation. Africa even though she has the highest rate of population growth rate, the disappearance rates of forest is actually lower than Asia and Latin America. The rates are pegged at 0.21%, 0.42% and 0.36% per annum for Africa, Asia and Latin America respectively (FAO, 2010).

Zimbabwe is well endowed with forests and woodlands covering over 53% of the total land area, 13% is covered by bush whilst 0.3% is covered by commercial plantations (FAO, 2010). Sadly, Zimbabwe is losing an average of 312 000 ha of forest per year (Manzungu and Mtali, 2012; FAO, 2010; Tevera, 2012). The situation has been compounded by the Fast Track Land Reform Program (FTLRP) that has seen more land being cleared by the new farmers so as to earn a livelihood. This historic loss of forests is closely married to demographic expansion and the conversion of forests into other uses. Poverty levels, an increase in demand of forest products and the precarious condition of the economy (Jeremy, 2010; Sachikonye, 2002), has seen an increase in forest degradation and a general increase in land use change.

Recently, case studies for change detection and management have started emerging in Zimbabwe due to an improvement of information communication and technologies that has facilitated easy access to data (Manzungu and Mtali, 2012; Tevera, 2012). Within this context, information on LULC change is crucial in planning and development of appropriate policies and program to militate against negative effects brought about by change. This research will henceforth help build on literature for LULC.

2.6 Accuracy Assessment

Accuracy assessment is defined as the degree of correspondence between observations and reality and is usually judged by comparison against existing maps, aerial photography or field assessments (Short, 2004). In the case of change detection, there are two types of accuracy assessment. The first being the identification of change and no change areas and the second being that of identifying the nature of the change. Three methods for the later type of accuracy assessment, the error matrix, Kappa coefficient and the normalized accuracy, are discussed in further detail.

- ***Error matrix***

The accuracy of a change detection or classification can be assessed by using an error matrix. An error matrix is a table that displays statistics for assessing the accuracy of an image classification or change detection by showing the degree of misclassification among the classes (CCRS, 2004). It is produced by comparing the classification with reference data acquired from ground truthing.

The matrix is a square array displays the raw number of pixels accurately classified and the number of pixels falsely classified (Table 2.1).

<u>Table 2.1: Representation of an error matrix</u>

		Field				
	Classes	A	B	C	D	Row Total
classification	A	**10**	1	2	3	16
	B	1	**15**	1	2	19
	C	2	3	**2**	3	10
	D	1	2	3	**5**	11
	Column Total	14	21	8	13	Grand Total: ***56***

Source: (CCRS, 2004)

The overall accuracy of the classification is calculated by dividing the diagonal total (sum of bold numbers) by the table total. In this case the overall accuracy is $32/56 = 57\%$. Two other statistics that are often reported along with the overall accuracy are the user's accuracy and the producer's accuracy. The user's accuracy indicates the probability that a pixel on the image actually represents that class on the ground (Story and Congalton, 1986; Daniel, 2002). It is calculated for each class by dividing the correctly classified pixels by the row total for that class, such that the user's accuracy for class A is 10/16=63%. The producer's accuracy is defined as the probability of a pixel being correctly classified and is mainly used to determine how well an area can be classified (Story and Congalton, 1986; Singh, 1989). The producer's accuracy is calculated for each class by dividing the number of correct pixels by the column total for that class, such that the producer's accuracy for class A is 10/14= 71%.

- ***Kappa coefficient of agreement***

The Kappa is a discrete multivariate technique used to evaluate the accuracy of change detection and classification maps by measuring the agreement between two images (Story and Congalton, 1986). It is calculated from the error matrix and measures how well the classification performs based on the referenced data (Jensen, 1996). The rationale for this technique is based on the probability of pixels being assigned to a class solely based on random chance (CCRS, 2004). The probability of a pixel being assigned to a particular class increases as the number of classes belonging to that class increases. The kappa coefficient indicates how accurate the classification is after accounting for this probability of random chance classification and is calculated by subtracting the change of agreement from the actual agreement of the error matrix (CCRS, 2004).

- ***Normalized accuracy***

Normalized accuracy is also based on the error matrix. However, it uses an iterative proportional fitting procedure that forces each row and column within the error matrix to sum to one (Story and Congalton, 1986). This eliminates the problem of having different class sample sizes and as a result, the cells within the matrix can be directly compared (Story and Congalton, 1986).

2.7 Application of LULCC

Change detection has many applications ranging from vegetation mapping, timber harvesting plans, urban sprawl detection, flood monitoring, mining and natural disaster damage assessment. Specifically, change detection is used in agriculture for predicting crop yields and for global monitoring of food and fibre production (Cracknell and Hayes, 1991). Forestry applications include inventory updating as well as fire and damage detection. FAO has been using change detection on satellite imagery since the early 1980's for the purpose of monitoring global changes in forest conditions. The Earth surface is changing constantly in many ways. Changes occur at various spatial and temporal scales in numerous environments. Change detection techniques are employed for different purposes such as research, management, or business. Monitoring changes using GIS and RS is therefore used in a wide field of applications. A non-exhaustive list of key applications is presented here as developed from Singh (1989) and Théau (2013).

2.7.1 Forestry

- Deforestation for example clear-cut mapping, and assessment of regeneration of forests. The process of fire monitoring including aspects such as delineation, severity, detection, and regeneration among others.
- In forestry logging planning can be done and monitor issues such as infrastructures, inventory, and biomass.
- Ecosystems management in herbivory such as insect defoliation, grazing and habitant fragmentation focusing on aspects such as land cover changes, heterogeneity, and ecological integrity

2.7.2 Agriculture and Rangeland Management

- Crop monitoring can be done with respect to growing and biomass
- Invasive species in aspects of detection and location or distribution.
- Soil moisture condition can also be investigated thus providing key information on irrigation farming, drought, flood, and natural hazards such as landslides.
- Desertification assessment can also be done for example bare ground exposure and wind erosion.

2.7.3 Urban

- The advent of urbanization especially in African cities and towns has seen an increased demand of services for proper management of urban issues such as urban sprawl hence LULC changes can be used to do urban mapping.
- In the same context, other issues that can also be done through LULC using GIS and RS include transportation and infrastructure planning such as land cover use. The data can be integrated with the requirements of the provisions of the Regional Town and Country Planning Act (Chapter 29: 12).
- Georisk assessment and management can also be done especially in the context of urban areas where most people live. These georisk features include earthquakes and volcanoes among others.

2.7.4 Ice and Snow

- Navigation route especially in sea ice motion.
- Infrastructure protection when considering the process of flooding monitoring.

2.7.5 Water, Ocean and Coastal

- Water quality assessment and monitoring can be done focusing on characteristics like temperature and productivity. This will include aquaculture.
- Erosion and vegetation mapping can be done so as to have facilitated intertidal zone monitoring.
- Water ecosystems are highly fragile and can suffer great damage from human actions such as accidents of oil spills. Change detection and management can be applied with respect to the detection of oil spills and movement.

2.8 Change Detection Methods

2.8.1 Image Differencing

Most change detection techniques require a more detailed quantitative approach than the visual composite methodology. In such cases, image algebra can be used and is a widely used change detection technique that involves band subtraction (Singh, 1989; Théau, 2013). The subtraction method involves subtracting a digital number value from one date of a specified band from the digital number value of the same pixel in the later date (Théau, 2013). Both images must be rectified to the same base map. The subtraction results in positive and negative values where change has occurred and zero values where no change has occurred (Mas, 1999). In simple terms, the values are obtained using the mathematical equation:

$$Id\,(x,\ y) \ = \ I1(x,\ y) \ - \ I2(x,\ y),$$

Where $Id\,(x,\ y)$ is the resultant image representing the intensity of change, $I1$ and $I2$ are images obtained from time $T1$ and$T2$, respectively and $(x,\ y)$ are the coordinates of the pixels. The resulting image, *Id,* represents the intensity difference of *I*1 from *I*2. According to Mas (1999), this technique works only if images are registered.

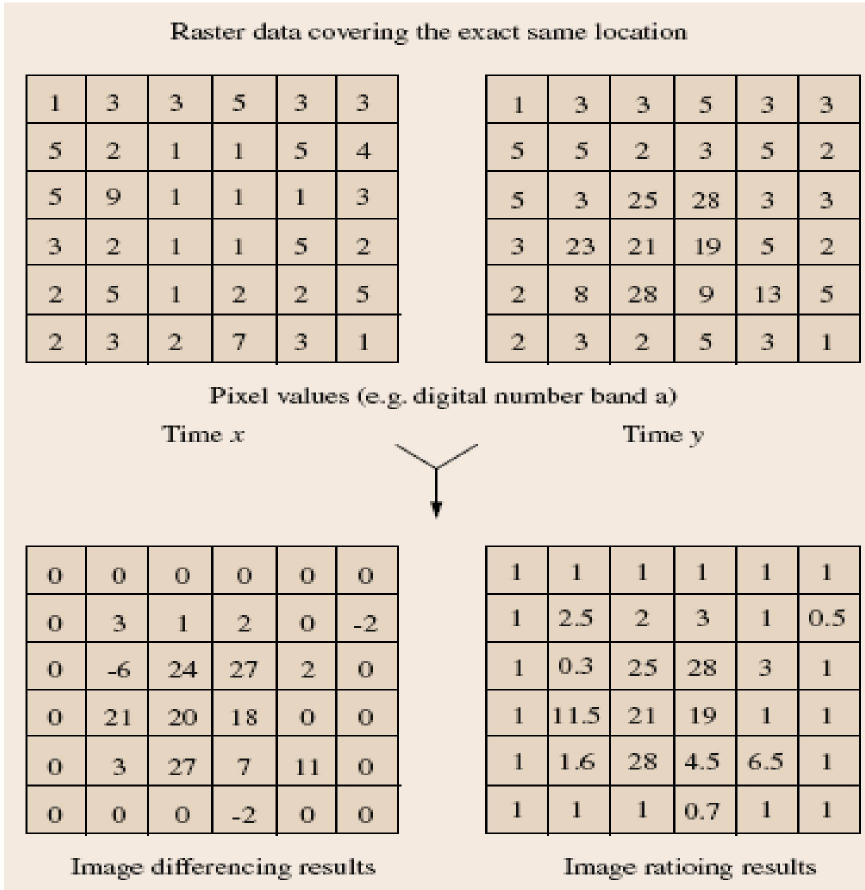

Figure 2.1: Image differencing and image ratioing procedures. Source: **(Théau, 2013).**

To interpret the difference image, it is important to note that the basic premise in using remote sensing data for change detection is that changes in land cover must result in changes in radiance values and changes in radiance due to land cover change must be large with respect to radiance changes caused by other factors (Cracknell and Hayes, 1991; Théau, 2013). Based on this principle, it is expected that intensity differences due to land cover change resides at the tails of the difference distribution of the image. Assuming that changes due to land cover are less than changes by other factors, it can be noted then that most of the difference is distributed around the mean.

2.8.2 Image Ratioing

Similar to image differencing, images are compared pixel-wise in this method. Therefore, images must be registered beforehand. The ratio image, used in this method, is calculated by the formula

$$Image\ Ratio = \frac{I2(x,y)}{I1(x,y)}$$

Changes are represented by pixel values higher or lower than 1 (as shown in Figure 2.1 above). Pixels with no change will have a value of one. In practice, for the same reasons as in image differencing, the challenge of this technique is in selecting threshold values between change and no change. This technique is often criticized because the non-normal distribution of results limits the validity of threshold selection using the standard deviation of resulting pixels (Shiferaw, 2011).

2.8.3 Image Regression

In image regression, the $I2$ image (obtained from $t2$) is assumed to be a linear function of the $I1$ image (obtained from $t1$). Under this assumption, an estimate of $I2$ can be found by using least-squares regression as $\hat{I}2(x, y) = aI1(x, y) + b$. To estimate the parameters a and b, a definition of the squared error between the measured data and predicted data (for each pixel) is done (Daniel, 2002).

2.8.4 Change Vector Analysis

Change Vector Analysis (CVA) is a technique where multiple image bands can be analyzed simultaneously. This technique uses change vectors to describe the direction and magnitude of the difference in pixel values between dates (Théau, 2013; Singh, 1989). As its name suggests, CVA does not only function as a change detection method, but also helps analyzing and classifying the change. In CVA, pixel values are vectors of spectral bands. The type of change that has occurred can be determined by the angle or direction of the change vector. Change vectors (CV) are calculated by subtracting vectors pixel wise as in image differencing. The magnitude and direction of the change vectors are used for change analysis (Daniel, 2002). The change vector magnitude can indicate the degree of change. Thus, it can be used for change and no-change classification.

Under ideal conditions, such as perfect image registration and normalization, unchanged pixel magnitudes must be equal to zero. However, this is not the case in practice. Therefore, thresholding must be applied to the change magnitude. While the change vector magnitude behaves like a multi-band version of the image differencing, the change direction gives us additional information about the change type (Daniel, 2002). This is often more valuable than the amount of change, since in most applications interest is vested in a specific change type. The type of change is then placed on a black and white base map of the region and the changed pixels are colour coded according to their directions. In practice, the number of CV directions is uncountable. Therefore, it is necessary to quantize the CV space and assign directions accordingly.

2.8.5 Post Classification Comparison

This technique classifies date 1 and dates 2 images separately and compares class values on a pixel-by-pixel basis between the two dates (Ernani and Gabriels, 2006). According to Jensen (1996), the method avoids problems encountered at the pixel level such as shadows and reflections and requires both images to be individually rectified and classified before they can be compared pixel-wise. This pixel-by-pixel comparison is accomplished using a change detection matrix but care must be taken to ensure that both classifications are as accurate as possible since any errors that occur in the classification will be carried over into the change detection.

PCC also provides good from-to information and results in a base map that can be used for the following year since identification of where change has occurred is done including how much it has occurred. However, some scholars and RS specialists argue that producing a change map based on two classifications requires a little more grunt work and the final change classification is only as accurate as the product of multiplying the accuracies of each individual classification (Stow et al. 1980 as cited in Lambin and Strahler, (1994); Daniel,2002)).

2.9 Chapter Summary

The chapter provided an over view of literature based on developments in LULC changes and management. Historical estimates at global, regional and local levels are also provided. Discussions on accuracy assessment are done to justify the importance of using GIS and RS as tools for change detection and management. A briefs explanatory note is given for the various change detection methods that are available at the disposal of the GIS and RS expert.

CHAPTER 3 : RESEARCH METHODOLOGY AND DATA COLLECTION

3.1 Introduction

This section describes the study area in terms of its climatic conditions, soils, vegetation and demographic characteristics. Methods and techniques employed for data collection and analysis are also described in detail. Data from Landsat Satellite imagery of October for 1986, 1998 and 2014 were used.

3.2 Background of Muzarabani District

3.2.1 Physical Characteristics

Muzarabani is a Shona name that means a plain or valley that is frequently fully covered with water. It is a district in Zimbabwe's administrative province of Mashonaland Central and is home to a wide array of tree species. The district lies between latitudes 15° 57′ 0″ S to 16° 51′ 42″ S and longitudes 30° 47′ 42″ E to 31° 30′ 0″ E. It has an average elevation of s 474m above sea level and is also known as Centenary, a colonial name derived from the colonial administrative government. The area dissected by rivers such as Hoya, Musengezi and Chadereka and bounded by the international boundary of Zimbabwe and Mozambique, to the north very close to Cahora Bassa Dam. Mavuradonha mountain range centrally cuts the district from east to west. The district has a Savannah type of climate and covers the Lowveld of the plateau of Zimbabwe. Summer temperature ranges from 22 to 42°C and 15 to 22°C during winter. Rainfall is mainly received in the summer season from the period covering middle of November to late February or mid-March and averaging about 530 mm. The area spans in region III, IV and V of Zimbabwe's agro-ecological zones. It is dominated by sandy loamy soils that are well drained (Nyamapfeni, 1991). Small-scale crop production, market gardening and animal husbandry are hence the predominant economic activities in the area.

3.2.2 Population and Demographic Data

The 2012 national population census puts the residents of Muzarabani at 122 791 constituting 10.7% of the total population of Mashonaland Central Province. The district has an average household size of 4.5 and is one of the poorest districts boasting of only seven better resourced secondary schools. Table 3.1 below gives a summary of the ward population based on the 2012 national population census.

Table 3.1: Summary of Muzarabani Population Distribution by Sex and Household

Ward	Population							Households	
	Males		Females		Total				
	Number	Percent	Number	Percent	Number	Percent	Sex Ratio	Number	Average Size
Total	61160	49.8	61631	50.2	**122791**	100	99.2	26928	4.6

Source: (ZIMSTAT, 2013)

3.2.3 General Livelihoods

A traditional chief and a team of village heads are the local leaders of most communities in Muzarabani District. The community developed values that are upheld by most of the members in conservation and other social dimensions. The local leaders are regarded as the custodians of the natural resources. The resources are common property and the members of the community share the rights to use or exclude others from using the resources. Such a set up has a huge bearing on LULC change management as land communally owned is allocated following this system of governance. Centenary is relatively a young agricultural district of Zimbabwe. It was opened up from virgin bush in 1952 primarily for the production of tobacco. The aromatic qualities of this tobacco made it a prominent growing area. Tobacco contributed to the development of roads, schools, clinics and the later building of administrative buildings in Centenary Township. In the Zambezi Valley, the main livelihood is crop farming, market gardening and animal husbandry, mainly cattle and small goats.

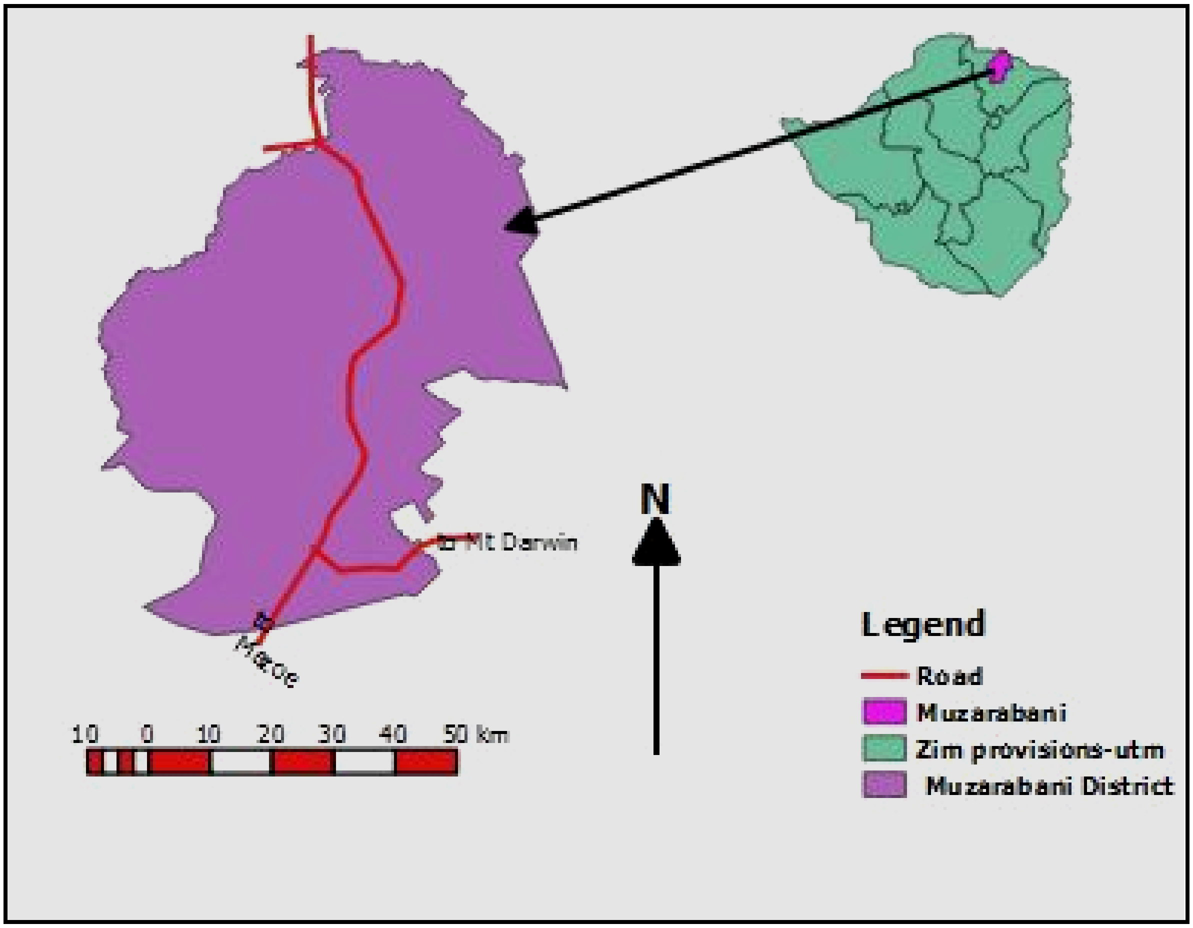

Figure 3.1: Muzarabani District, Zimbabwe.

3.3 Conceptual Framework

The procedure adopted in this study forms the basis for the derivation of maps and data on land use dynamics and subsequently, the overall findings of the research project. No research methodology is perfect in terms of guaranteeing validity and reliability (Maxwell, 2012). The two types of research methodology, qualitative and quantitative were used. Qualitative research is said to be empirical research where the data are mainly in the form of numbers, whereas qualitative research has data mainly in the form of deep explanations of phenomena and experiences (Punch, 2005). Therefore, to this end the researcher triangulated qualitative and quantitative data collection methods, where quantitative methods were used mainly to come up quantities seen in changes that would have occurred whilst qualitative was used to provide an insight of why the changes occurred especially in the human-development nexus.

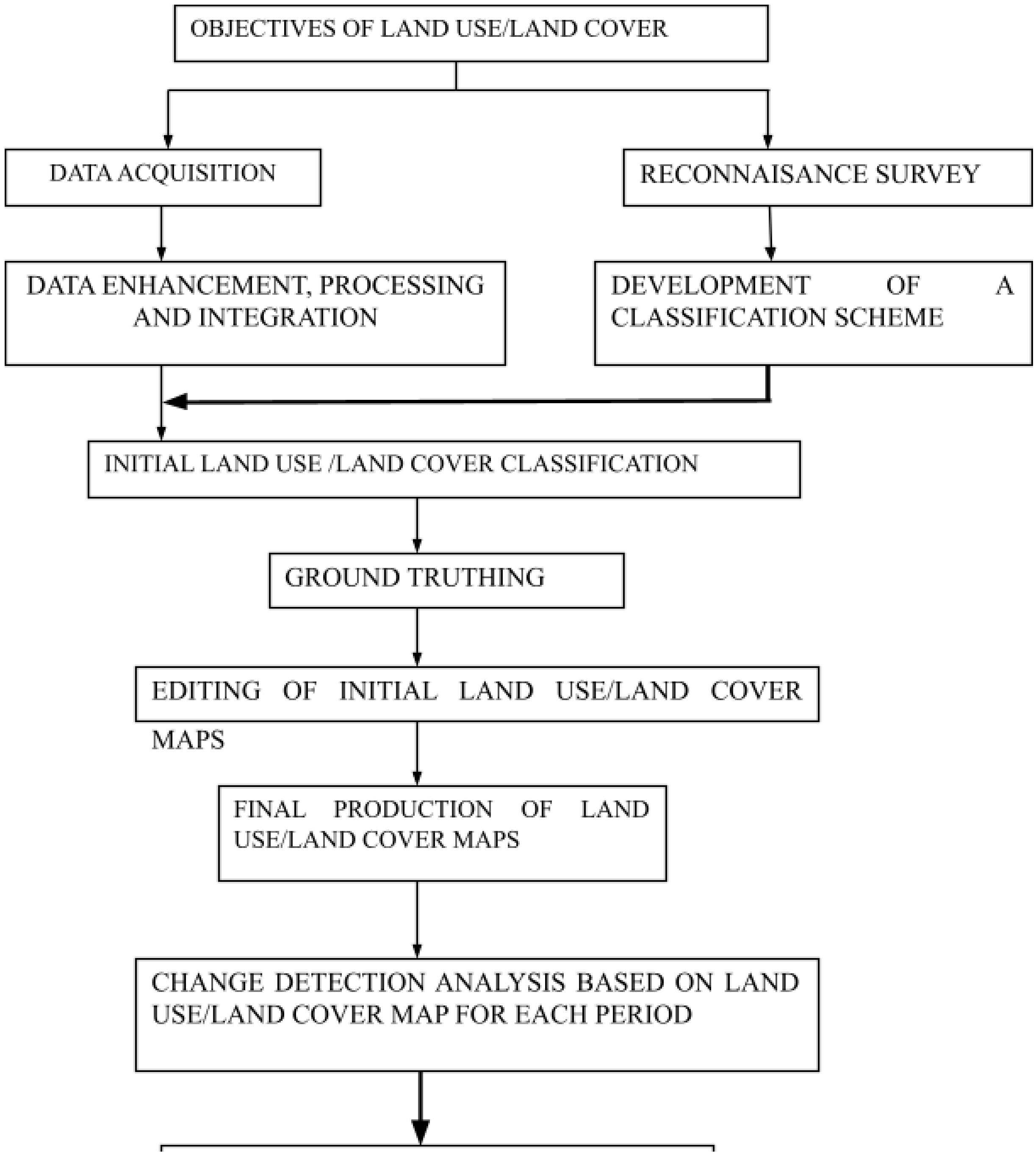

*Figure STYLEREF 1 \s 3. SEQ Figure * ARABIC \s 1 2: Conceptual Framework of the Research Study*

3.4

3.4.1 Image Acquisition of Remote Sensed Data

Landsat satellite data is increasingly becoming the most widely used data type for land cover mapping not only because of its over thirty-five year data record, but also due to its relatively high spatial resolution and generally easy accessibility. For the study, Landsat satellite images of Muzarabani were acquired for three, 1986, 1998, and 2014 from the Global Land Cover Facility which is an Earth Science Data Interface. These images which were geo-referenced, radiometrically calibrated and otho-rectified were obtained from the earth explorer website (http://landsatlook.usgs.gov/viewer/.html). A summary of the Landsat Images used is presented in Table 3.1 below:

Table 3.2: Satellite Images Used In This Study

	SENSOR		
Characteristic	*Landsat 5*	*Landsat 5*	*Landsat 8*
Temporal Resolution	October 1986	October 1998	October 2014
Path-Row	170-71	170-71	170-71
Spatial Resolution	30m by 30m	30m by 30m	30m by 30m

Source: (USGS, 2015)

There are many reasons why Landsat satellite images were used in this study. Chief among these is that the images have excellent price-quality and better spatial characteristics of 30m by 30m. It has also been noted that decreasing costs, easy availability and accessibility have enhanced the adoption and integration of GIS in decision making, planning and modelling all for the benefit of mankind (Buckey, 2011; Short, 2004; Dimyati, 1995). Unfortunately, Landsat image classifications are commonly conducted on scene at a time, which limits the rapid analysis of large areas (Cihlar, 2000). Image acquisition dates are quite important so as to avert variations in reflectance caused by seasonal vegetation fluxes and solar angle and this was underscored by other researchers (Cracknell and Hayes, 1991; Ernani and Gabriels, 2006; Manzungu and Mtali, 2012). This therefore formed the basis of the reason why October was used for the three images. In addition, cloud cover would be at its lowest rate during this time in Muzarabani.

3.4.2 Land Cover Data

Reliable training and validation data is prerequisite for meaningful land cover mapping. A sample of twelve points was selected for each of the five land cover category. Google earth was used for the selection of the points based on visual interpretation of images. The aim was to identify the land cover type and then associating the land cover type with image characteristics especially during image processing using ENVI version 4.7.

3.4.3 Secondary Data

The researcher used texts, the internet, newsletters, journals and statutory returns as secondary data sources. Secondary data helped the researcher to form the basis and platform to extract objectives, the problem in reality and the solution thereof. In addition, population data for Muzarabani District was obtained from the publications of ZIMSTAT, the organisation mandated to carry out censuses and surveys.

3.5 Data Processing and Land Classification

3.5.1 Image pre-processing

The images were geometrically corrected and geocoded to the Universal Transverse Mercator (UTM) coordinate system using 12 ground control points (GCPs). Re-sampling was applied using a nearest neighbour method. Radiometric normalization was necessary to reduce differences because of atmospheric or a sensor variation. In this study, the images were radiometrically normalized based on the method built in the ENVI software called FLAASH.

3.5.2 Image Processing

Image processing software ENVI 4.7 and GIS software, Q-GIS 2.8.1 were used for processing of the images. The raw images were converted from the tag image file format (.tiff) in order to be compatible with other ENVI 4.7 images. Clipping of data corresponding to Muzarabani was done focusing mainly to areas that fall within the Landsat image listed above. Band combination of Red, Blue and Green (RBG) was used to display the raw images in standard colour composites. The spectral band combination for displaying images often varies with different applications (Gong and Howarth, 2012; Kwesha, 2005). This study thus used a RBG combination for land cover and vegetation mapping.

3.5.3 Image and Land Classification

Image classification is the process of creating thematic maps from satellite images (Anderson et al, 1976; Lambin and Strahler, 1994). Similarly, image classification can be defined as the process of automatically categorizing all pixels based on their spectral properties into land cover classes (Lillesand and Kiefer, 1999; Cracknell and Hayes, 1991). This gives rise to two methods of image classification: supervised and unsupervised. Supervised is dependent on the input from the user and informational classes known previously (Kwesha, 2005). The major advantage of this method is in the accuracy of the image classified since validation is done through ground truthing. For this research four broad groups were used: forests; water; cultivation and grassland/bush land. Accuracy assessment was done to determine the levels of accuracy and errors in the image classification process.

3.5.4 Change Detection

In order to detect land cover changes, the main method used was image differencing as this method is relatively easy to use. The changes are noted by having a positive or negative value for the time intervals, 1986-1998, 1998-2014 and 1986-2014. The results are fully described and discussed in Chapter 4. ENVI 4.7 was used for image differencing and hence detection of change with the output maps being exported to Q-GIS 2.8.1 for further analysis and production of the maps. There is no ideal classification of land use and land cover and it is unlikely that one could ever be developed (Cihlar, 2000; Ernani and Gabriels, 2006). Classification schemes are abstractions or generalisation of reality. As such, an analysis of the local trends of land cover for Muzarabani District was based on the adopted land cover classification scheme that includes generalisations from FAO. An extract is shown in Table 3.3 below.

Table 3.3: Land Cover Classification Scheme

Class	Description
Forest	Land spanning more than 0.5ha with trees higher than 5m and canopy cover of more than 10%, or trees able to reach these thresholds insitu. Man made forests are included.
Woodland	Land not classified as forest, spanning more than 0.5ha with trees higher than 5m and canopy cover of 5-10%, or trees able to reach these thresholds insitu or with a combined cover of shrubs, bushes and trees above ten percent.

Source: (FAO, 2010)

The rate for LULC change was also calculated based on a formula which was also used by Shiferaw (2011).

3.6 Limitations to the study

The limitations to this study are based on the fact that the research area is huge in spatial extent such that it was not possible to cover each area in detail. In order to countermand this drawback, a randomized approach was used based on the methods of image interpretation (texture, colour) during the selection of GCP’s. Software for image processing is generally expensive hence in order to get an appreciation of the stages in image processing permission was sought from other GIS and RS experts to lend their software for use. As for the challenge of access to internet resources during the day especially in accessing Landsat imagery, night time slot were made use of since data traffic would be at its minimal. A valid student identity card coupled with a national ID card was produced and when the need arose.

3.7 Chapter Summary

The chapter described how the study was carried out for and in Muzarabani District including all the activities and procedures undertaken during the course of the research. The chapter also provided information on the demographic and climatic information for the study area. The conceptual framework of the research design, data collection tools and methods were outlined. An overview of the data analytical process is also done.

CHAPTER 4 : DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

The main findings of the research are provided in this chapter especially pertaining to the objectives as set out in Chapter 1. LULC maps for 1986, 1998 and 2014 are also produced. A land cover change map for each time period is also provided so as to give an overview of the changes that would have been noted. Changes are noted these have been augmented by statistical information including rates of change that would have occurred.

4.2 Data Analysis Method

The main analytical procedures included image pre-processing, supervised classification, accuracy assessment, and post classification change detection. The process of geo-referencing of different multi-temporal remote sensing data was done using geo-referenced Ordinance Survey of Zimbabwe topographical map by identifying the ground control points (GCP's) from the map and the corresponding points on the satellite images. Google Maps and Earth Explorer were also used to provide for acquisition of GCPs and finally applying the map-image transformation model. The World Geoids System (WGS84) and Universal Transverse Mercator (UTM) projection were used as these are standard and in built in GIS software. On-screen analysis of the clipped satellite data was done and Q-GIS used to produce the maps.

While there are two different image processing classification methods, supervised and unsupervised, the study used the supervised classification method. Supervised classification is the process of using training samples, samples of known identity to classify pixels of unknown identity (Manzungu and Mtali, 2012; Pandy and Nathawat, 2006). Broadly the area was divided into four classes namely: forest, water bodies, cultivation, and grassland/bush land, the reasons for coming up with these classes was based on the nature of cover that was inherent in the clipped images.

4.3 Image Interpretation

4.3.1 Elements on which image interpretation are based

Human eyes can differentiate over 1000 colors but only about 16 grey levels (Ernani and Gabriels, 2006). Image tone, grey level, or multispectral grey-level vector is one element that can be used in image interpretation. Therefore, colour images are preferred in image interpretation.

One difficulty involved is use of multispectral image with a dimensionality of over three. In order to make use of all the information available in each band of image, one has to somehow reduce the image dimensionality. In addition, image texture, which is spatial variation of image tones, can be used. Texture is used as an important clue in image interpretation and is very easy for human interpreters to include it in their mental process. Most texture patterns appear irregular on an image.

Pattern can also be used in image interpretation with such characteristics as a regular arrangement of ground objects indicating residential areas on an aerial photograph and mountains in regular arrangement on satellite imagery. It can also be based on association where a specific object co-occurring with another object. Some examples of association are an outdoor swimming pool associated with a recreation center and a playground associated with a school.

Object shadow is very useful when the phenomena under study have vertical variation. Examples include trees, high buildings, and mountains, whilst agricultural fields and human-built structures have regular shapes. These can be used to identify various targets. Size and site are also used in image interpretation as relative size of buildings can tell one about the type of land uses while relative sizes of tree crowns can give a picture about the approximate age of trees. Broad leaf trees are distributed at lower and warmer valleys while coniferous trees tend to be distributed on a higher elevation, such as tundra hence location is used in image interpretation.

4.3.2 Image interpretation strategies

A variety of strategies can be used such as direct recognition of targets such as land-cover classification. Indirect interpretation is done which involves mapping something that is not directly observable in the image. This is used to classify land use types (Gong and Howarth, 2012). Land-use is the human activities on a piece of land and is closely related to land-cover types. For example, a residential land-use type is composed of roof cover, lawn, trees and paved surfaces. Another strategy to interpret images from known to unknown and to interpret an area where the interpreter is familiar with first, then interpret the areas where the interpreter is not familiar with (Théau, 2013; Gong and Howarth, 2012). This can be assisted by field observation.

The 'from direct to indirect' strategy is based on the idea that in order to obtain forest volume, one might have to determine what is observable from the image, such as tree canopies and shadows.

4.4 Land Cover Maps

Three thematic maps (figures 4.1 to 4.3) in this subsection show the land use and land cover types that have been generalised for Muzarabani District and these were extracted from Landsat 5 and 8. The following general land classification schemes were used.

Table 4.1: Description of LULC Classes

LULC type	Description
Forest	Canopy cover more than 10%, mostly tress
Grassland/Shrubs	Canopy cover less than 10%, a lot of grass
Cultivation	Areas covered by growing crops, ploughed fields
Water	Open waters, rivers, lakes,

Source: Adapted from (FAO, 2010)

The dominant land cover for 1986 was grassland as shown on the land cover maps. Pressure on land as a resource and livelihood was still very low but that changed with the effects of cohort flow of population as the youths migrate into parenthood, hence needing land so as to be self sufficient. Cross relation of data generated by the 1998 land cover map with flood history indicates that the district was still punctuated by spots of water from various cyclone and weather conditions of 1997/8/9. The situation was compounded by the backflow of Cahora Bassa Dam.

4.4.1 Land Cover Classification for 1986

Figure 4.1: Land Cover Classification for Muzarabani derived from Landsat Images of October

4.4.2 Land Cover Classification for 1998

Figure 4.2: Land Cover Classification for Muzarabani derived from Landsat Images for October 1998

4.4.3 Land Cover Classification for 2014

Accuracy assessment was done by using ENVI, the image processing software and confusion matrix was generated which also provided a Kappa coefficient. This was done for the 2014 Image as data for ground truthing was available. As for the 1986 and 1998 images, nothing was done because of the absence of ground truthing data.

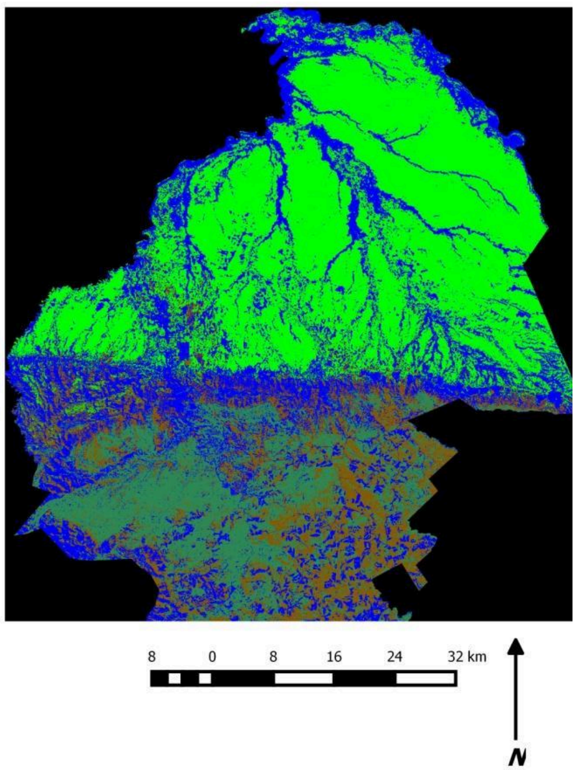

Figure 4.3: Land cover classification for 1990

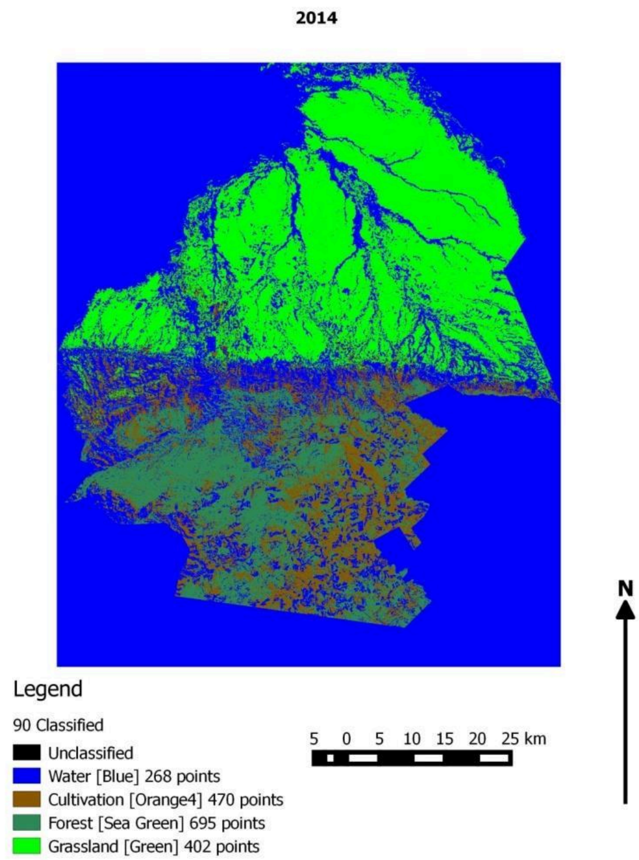

Figure 4.4: Land cover classification for 2014

Land Cover Change Detection

Pursuant to the aim of this research, a change detection map has been generated for the two time intervals so as to get an understanding of the nature of change and the quantity of change.

4.4.4 Land Cover Change Detection 1986 to 1998

4.4.5 Land Cover Change Detection 1998 to 2014

4.5 Accuracy Assessments

Accuracy assessment was done for the 2014 image as ground trithung data was available

Table 4.2: Error matrix for 2014 image classification

		Field Observation				
	Classes	A	B	C	D	Row Total
Classification Data	A	*25*	16	3	11	55
	B	4	*34*	4	4	46
	C	5	3	*15*	3	26
	D	13	16	5	*21*	55
	Column Total	47	69	27	39	**182**

4.6 Discussion of Results on Land Cover Change

4.6.1 Nature of Change in Land Cover

The results indicate that over the twenty eight year history, LULC change has been associated with an increase in crop farming and a reduction in forest land. These findings are in line with other researches Land left fallow will soon regenerate to form new land covered by shrubs and grass.

4.6.2 Rate of Change

4.6.3 Land Consumption rate

4.7 Chapter Summary

The chapter provided an overview of the research findings thus answering the main aim of why this study was carried out. The findings include the fact that natural forests are on the decline whilst man is expanding land under cultivation. The rate of change was thus also calculated to determine the land consumption rate. A model was also used to analyse the findings especially pertaining to the socio-political and economic interaction.

CHAPTER 5 : SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

Land cover maps have been generated for 1986, 1998 and 2014. The chapter presents a summary, conclusion and recommendations based on results of this study.

5.2 Summary

Land cover classification was done with only four classes being used to provide a simplified picture. The thematic maps show the land cover types for each year and they were extracted from Landsat TM images. Ground truthing was done in relation to image for the year 2014 and statistics were derived based on this. The results show land cover change mainly associated by a reduction of forest land with an associated increase in land under cultivation. Most land cover has been converted into cultivation especially for the period 2005 onwards as compared to prior and this augurs well with the emerging trend observed in land that used to belong to former commercial white farmers. Whilst it was not within the scope of this study, other causes of land cover change are drought, gold panning and policy framework like the Regional, Town and Country Planning Act (Chapter 29:12) that identified the nature of land use thus affecting land cover.

The most important issue in land cover change detection is identifying the nature of change occurring, for instance, is it forestry to cultivation? This is a useful tool especially in natural resource inventory planning and management. Decision making systems are not only supported but they are also enhanced. Land cover change maps can be sued to potray a picture o the places where change is occurring. In addition land consumption rates can be calculated for each land cover type. For Muzarabani this ranged from to by changes in climate and the reduction in importance attached to the local traditional systems of resource conservation and management.

5.3 Recommendations

The findings of this research show that land cover changes are a real phenomena and GIS and RS are effective tools in detecting these changes. In addition, the tools provide statistical information like the rate of change. The findings of the research study therefore recommend the following:

The following recommendations can also be adopted:

- The potential use and superiority of GIS and RS in monitoring resources use change and it is imperative that a framework for the integration of GIS and RS be developed to continuously and timeously monitor land cover changes. This is premised on the fact that the tools can be used to detect type of change and also to calculate the rate of change,
- As changes in land use become more pronounced, there is need to use GIS and RS since they are important tools that can be adopted especially in developing models to simulate feature conditions. For disaster prone areas, effective early warning systems can thus be developed.
- Within the same context, adequate continuous monitoring of land cover and land use needs to be done by making use of satellite remote sensing and GIS technologies so that a stock of the district and the nation's resources can be aptly managed and captured. This will help in the formulation of policies that are informed.
- The responsible authorities should make frantic efforts to complement efforts of environmental education so that there is better management of environmental resources and increased protection of resources. This becomes paramount especially in the face of globalisation and the need to shift towards the SDGS.
- More research needs to be done especially pertaining to land cover change especially from forest to agriculture as strategies like agriculture intensification can be adopted as compared to extensification. Forests play a crucial role in the biosphere as they act as carbon sinks.

5.4 Conclusion

Developments and applications of new image processing methods and geospatial analysis are also expected in the next decades. These techniques have gained considerable attention in the past few years and are expected to increase in change detection approaches in the future. One of the main advantages of these techniques is that they allow the integration of existing knowledge and non-spectral information of the scene content. Some of these have been used to detect the changes in land cover within Muzarabani District. Secondly, a change detection map can be produced for those areas under study and with the use of colour, can explain the nature and distribution of change. This simply shows the central role of GIS and RS in change detection and management of LULC.

In addition, GIS and RS related tools are powerful in the management of resources as they can be used to provide statistical data like the nature and magnitude of change. Land consumption rates can also be produced so that resource allocation can be done effectively. With the increasing interest in using integrated approaches such as coupled human–environment systems, the blending of non spectral information makes the prospects of development to look promising. The recent integration of change detection and spatial analysis modules in most GIS software also represents a big step towards integrated tools in the study of changes on the Earth surface. This integration also includes an improvement of compatibility between image processing software and GIS software. More developments are expected in the future which will provide new tools for integrating multisource data more easily for instance digital imagery, hard maps, historical information, and vector data thus providing a wide base for their use in change detection. .

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5.6 APPENDICES

5.6.1 Annexure 1: Population

Table 5.1: Muzarabani Population Distribution by Ward, Sex and Household

Ward	Population							Households	
	Males		Females		Total				
	Number	Percent	Number	Percent	Number	Percent	Sex Ratio	Number	Average Size
Ward 01	3459	49.2	3573	50.8	7032	100	96.8	1456	4.8
Ward 02	3195	49.8	3219	50.2	6414	100	99.3	1345	4.8
Ward 03	1369	49.4	1402	50.6	2771	100	97.6	622	4.5
Ward 04	2525	49.1	2617	50.9	5142	100	96.5	1109	4.6
Ward 05	2399	48.1	2589	51.9	4988	100	92.7	1118	4.5
Ward 06	1066	49.1	1103	50.9	2169	100	96.6	481	4.5
Ward 07	637	49.2	658	50.8	1295	100	96.8	286	4.5
Ward 08	2800	49.2	2895	50.8	5695	100	96.7	1390	4.1
Ward 09	2221	48.7	2341	51.3	4562	100	94.9	997	4.6
Ward 10	4065	48.0	4401	52.0	8466	100	92.4	1851	4.6
Ward 11	1604	49.6	1627	50.4	3231	100	98.6	674	4.8
Ward 12	2507	51.4	2368	48.6	4875	100	105.9	1084	4.5
Ward 13	1481	52.6	1335	47.4	2816	100	110.9	610	4.6
Ward 14	3612	51.6	3386	48.4	6998	100	106.7	1561	4.5
Ward 15	1594	47.4	1769	52.6	3363	100	90.1	865	3.9
Ward 16	836	50.4	823	49.6	1659	100	101.6	343	4.8
Ward 17	2937	49.1	3046	50.9	5983	100	96.4	1329	4.5
Ward 18	1133	48.1	1221	51.9	2354	100	92.8	493	4.8
Ward 19	1678	50.0	1681	50.0	3359	100	99.8	757	4.4
Ward 20	485	47.0	548	53.0	1033	100	88.5	234	4.4
Ward 21	1136	48.8	1193	51.2	2329	100	95.2	490	4.8
Ward 22	952	50.2	945	49.8	1897	100	100.7	416	4.6
Ward 23	4761	51.0	4568	49.0	9329	100	104.2	1944	4.8
Ward 24	2973	50.2	2953	49.8	5926	100	100.7	1230	4.8
Ward 25	1426	50.4	1402	49.6	2828	100	101.7	593	4.8
Ward 26	1852	51.5	1745	48.5	3597	100	106.1	841	4.3
Ward 27	2249	49.1	2336	50.9	4585	100	96.3	1013	4.5
Ward 28	2766	51.6	2592	48.4	5358	100	106.7	1219	4.4
Ward 29	1442	52.7	1295	47.3	2737	100	111.4	577	4.7
Total	**61160**	**49.8**	**61631**	**50.2**	**122791**	**100**	**99.2**	**26928**	**4.6**

Source: (ZIMSTAT, 2013)