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Spatial-Temporal Analysis of Land Use / Land Cover Changes In Bindura District Using GIS And Remote Sensing.

BY

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DECLARATION FORM

I Melody Chibanda (B202117B), hereby affirm that this thesis is an output of my research and findings. The information outsourced from previous literature in this dissertation is fully acknowledged and a reference list is included. This work has not been previously submitted in part or entirety for any degree purposes to any other university. Submitted in partial fulfilment of the Bachelor of Science Honours Degree in Disaster Management at Bindura University of Science Education.

Signature. 

Date…… 4/06/24

APPROVAL FORM

The undersigned certify that they have read this project and have approved its submission for marking after confirming that it conforms to the Department's requirements.

Signed……………………Date…4 June 2024………

29/09/24

Prof E. Mavhura (Chairperson, DRR Dpt) **(Date)**

DEDICATION

This dissertation is lovingly dedicated to my mother, Ellen Mudondo and my sweet aunt Rice. Their support, encouragement and constant love have sustained me throughout my life.

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My first acknowledgement goes to Almighty God for seeing me through this mazy and rugged terrain. It was not easy, but his divine grace guidance surrounded me through triumphantly. All glory to him! I'm also indebted to my supervisor, Mr T Gomo whose intellectual prowess made everything possible. His guidance was important in doing this research that saw the production of this work full of logical flow of ideas and reasoning. I also want to acknowledge the overwhelming and constant support from my family and friends. Had it not been for your unwavering support, this noble enterprise would not have come to this happy ending.

ABSTRACT

Land use and land cover change is a common phenomenon in this contemporary world. This is being driven mainly by human activities which include urbanization, mining, agricultural activities and unsustainable exploitation of natural resources like timber/wood. However, changes in Land Use and Land Cover (LULC) have both beneficial and adverse impacts to the welfare of men and the sustainability of ecosystems which is strongly dependent on the type of change. It is against this background that this research used GIS and Remote sensing techniques to determine changes in Land Use and Land cover in Bindura District, with the aim of identifying the drivers of change and the associated impacts, so as to stimulate proactive risk informed decision making to reduce Disaster risk in Bindura district by monitoring and controlling land use and lad cover change. Landsat 8 images were acquired and processed for the 2002, 2012 and 2022 and the overall accuracy assessment was 78%. The research provided empirical evidence of anthropogenic conversion drivers, spatially delineated hotspot changes and highlighted need for pragmatic land use planning and community-based management strategies to curb further degradation and promote green growth around urbanizing

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ACRONYMS

AI	**Artificial Intelligence**
DEM	**Digital Elevation Model**
EM	**Electromagnetic**
EP	**Environmental Protection Agencies**
GIS	**Geographical information system**
GP	**Geographical Position System**
LULC	**Land Use Land Cover**
ML	**Machine Learning**
NDVI	**Normalized Difference Vegetation Index**
RF	**Random Forest**
RS	**Remote Sensing**
USGS	**United States Geography Survey**

CHAPTER ONE

1.1 Introduction

The negative consequences that land cover changes frequently bring with them have made them a source of concern for people all over the world. Variations in land use and cover are present in the transitions, and they can be broadly characterized in terms of both temporal and spatial dimensions. Some land use/cover types may completely change into a different kind as a result of the alterations. Conversions can take the shape of agriculture replacing, say, woodland. In contrast, in other regions, land cover changes refer to the partial conversion of one type of land cover into another while maintaining its primary status, such as the conversion of a natural forest into an alien forest.

1.2 Background of study

Most urban areas in developing countries are experiencing swift population growth and rising in rural areas to city migration(Ezeobi et al., 2023)It is estimated that globally 5 billion people will live in urban areas by 2025 (Gilbert, Katambara and ShiY, 2023). In Zimbabwe the percentage of individuals residing in metropolitan regions has increased since Zimbabwe's attainment of independence in 1980 from 26% in 1982, 35% in 2002, 36,8 in 2012 and 40% in 2015 (Murwira 2017) Such changes have been associated with landscape alteration

Regionally, countries adopted different strategies to curb land use changes. For example, South Africa selected populated centres in rural areas such as Kwazulu Natal, Ngcuwa and Trankel and provided them with piped water, sewage, internal roads and electricity (Msapa 2006). Tanzania adopted a radical rural development strategy that saw modernization of agriculture through farm mechanization and identification of key centres that were provided with piped water, sewage, internal roads and electricity (M. G. Munthali et al., 2019).

The Zimbabwean government adopted the growth centre strategy which saw growth points receiving public sector investment to encourage growth Settlement expansion in emerging nations has been recognised as the primary reason of land cover change (Athukorala, 2021). With the growing acknowledgment of settlement expansion as a contributor to alterations in l land cover change, essential and trustworthy information is required to monitor, analyse and predict the future trends of land cover change resulting from settlement expansion. Against this backdrop it is imperative to use remote sensing (RS) and Geographic Information Systems (GIS) techniques that are less expensive as well as reliable to update land cover maps.

Studies have shown that remotely sensed data, remote sensing techniques and GIS tools offer incredible chances to chart past trends of settlement growth, monitor urban and emerging urban areas and forecast expansion (Liyew et al., 2019).For example, a research was carried out in Cairo, Egypt to monitor urban growth between 1973 and 2006 (Hassan & Syakir, 2023). Moreover, Muli et al (2018) applied remote sensing and GIS techniques to monitor spatial growth of Rawangware informal settlement in Kenya between 1990 and 2010.

The study will be conducted in the Bindura district with special emphasis on forest, build-up area, agriculture area and the quantification of changes in woodland cover that occurred during the specified period range from 2002 to 2022 a period of 20 years. The research is vital to mitigate the local land cover change which will greatly impact the local, regional and global scale (Gondwe et al., 2021). The findings will help to identifying the problems in similar ecosystems and solving such local problems which have a wide range of impact, have significant importance on a global scale. Therefore, the current land use and land cover change of the country in general and areas with a rich biodiversity natural forests in Bindura district.

1.3 Statement of the problem

Swift population growth and increased economic activities such as mining and agriculture are on the raise as well as uncontrolled settlement growth or sprawling which causes various problems including change and ingestion of conservational land. It consumes precious farming lands in the periphery, results in landscape alteration, environmental pollution and neighbourhood conflicts (Albalawi et al., 2018). The UN Habitat (2019) noted that in order to attain sustainable development local authorities need to follow the fundamental principles of regional planning aimed at projecting development transition from the past to the future. However, in developing countries such as Zimbabwe, very little is known about past trends of land use and land cover changes growth thus making it difficult to project future growth of these areas. Hence there is a need to map historical patterns of settlement growth, monitor urban areas and forecast growth. Satellite imagery is especially useful in African environments where there is lack of or outdated historical land use change records. Against a scarce recourse of land this has seen a rapid change in Bindura District land use and land cover over a period of time (Hassan & Syakir, 2023). Therefore , extensive areas that were once covered with vegetation are now vulnerable to deforestation by mining activities and other developmental issues, yet this leads to environmental degradation and a serious threat to wildlife loss (Gondwe et al., 2021). Furthermore, the loss of the vegetative cover could result in biodiversity loss, which could lead to species extinction even though the rate differs with type of species due to its geographic distribution and abundance (Liyew et al., 2019). Local vegetation cover change, specifically forest cover change has significant and cumulative impact on regional and global climate changes, environmental problems have no boundaries and are interrelated (Mavhura et al., 2017).

The UN (2019) noted that in order to achieve sustainable development local authorities need to follow the basic principles of regional planning which seek to project development movement from the past to the future. However, in developing countries such as Zimbabwe, very little is known about past trends of land use and land cover thus making it difficult to project future growth of these areas. Hence there is a need to map historical patterns of LULC in monitoring urban areas and forecasting. Satellite imagery is particularly a valuable tool for African environments in which historical land-use change records are either not available or out-dated (Athukorala, 2021). The research proposes using Landsat (TM, OLI) and Sentinel (MSI) multi-spectral satellite images and GIS technologies to measure internal land cover changes over the past 20 years (2002–2022), which will be analysed over ten-year time periods (2002, 2012 and 2022).

1.4 Aim of the study

Spatial –Temporal analysis of human activities on land use and land cover changes in Bindura urban area using GIS and Remote Sensing.

1.5 Objectives of the study

i. To analyse land use cover changes in Bindura District between 2002 2012 and 2022.
ii. To detect homogeneous LULC types with the use of supervised spectral classification and remote sensing indices based on the spectral characteristics of individual land cover elements
iii. Analysis of the impact/effect of human activities on LULC in the study area

1.6Research questions

The following are the research questions the study will focus on:

i. What are the land use and land cover changes in Bindura?

ii. What are the homogeneous land use types in Bindura District?

iii. What are the impacts of human activities on LULC?

1.6 Justification of the study

1.6.1 Environment

The study will have an impact on the environment which needs monitoring and proper planning this gives the significance of the study in Bindura because no study has been done in assessing the rate of LULC using sophisticated systems such as GIS. Land use will be recognised as an important driver of environmental change in spatial and temporal scales. In the study, investigations are going to be done into how land use and land cover have changed over time (Roy and Roy 2020).

1.6.2 Environmental Protection Agencies

Environmental Protection Agencies such as EMA Land use and land cover changes facilitates land suitability analysis by providing data on terrain, soil characteristics, and vegetation cover. This information assists decision-makers in identifying suitable areas for specific land uses, ensuring optimal resource allocation and minimizing conflicts between competing interests.

1.6.3 Environmental Policymakers

Environmental policy is primarily concerned with how to govern the relationship between humans and the natural environment in a mutually beneficial manner.

1.7 Delimitation of study

The function of this study is focused on Bindura with special concern on land use and land cover changes in Bindura. Bindura district is developing at a fast rate, leading to high urbanization and hence a quick change in land use and patterns. As a result, it becomes an issue of both environmental and public concern to the authorities. The research identifies the impacts of land use and land use change practices about growth in settlement. Lastly, the focal point explored the rise in human activity impacted changes.

1.8 Definition of terms

Land use land cover change (LULC)

Land cover change denotes a change in certain continuous characteristics of the land such as vegetation type, soil properties, and so on (Patel et al., 2019). According to some scholars, land cover change can refer to the process of change in the type of land cover, which is the layer of vegetation, water, or other materials that covers the earth’s surface.

Land use refers to the ways in which humans use land and the resources on it. This can be including agricultural use, industrial use and urban development. According to International

Journal of Applied Earth Observation and Geo-information (2014) defines land use as the human activity or utilisation of land resources.

Remote sensing (RS) is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance. According to Remote Sensing of Environment Journal (2018) defines remote sensing as the science and art of obtaining information about objects or areas from a distance. Remote sensing is a form of geospatial technology that samples emitted and reflected electromagnetic (EM) radiation from the Earth's terrestrial, atmospheric, and aquatic ecosystems in order to detect and monitor the physical characteristics of an area without making physical contact (Purkis & Klemas, 2011).

Geographic Information Systems (GIS) is a computer system that analyses and displays geographically referenced information. International Journal of Spatial Data Infrastructures Research (2019) defines geographic information systems as a decision support system that uses computer based tools to collect, manage, analyse and visualise all types of spatial data and information.

1.9 Organisation of study

Using a mixed-method approach, the research is presented in five chapters, including an introduction. The first chapter will present background material and bring into light the concerns which the study wants to investigate which is the influence of human activities on Land Use / Land Cover Changes in Bindura District. The major goal of the research, which was based on the effectiveness of remote sensing and GIS techniques, was thoroughly detailed in this chapter.

A summary of the research problem, the primary goal, and its supporting objectives are also included in this chapter. An overview of the causes and effects of human activities on the environment that contribute to land use and land cover collapse (LULC) is provided via a review of the literature in Chapter 2. We'll talk about empirical research on how changes in land cover and use are impacted by human activity. The chapter also offers the analytical methodology local councils use to direct their assessment of LULC. The process for choosing research locations as well as the methods for collecting and analyzing data are covered in Chapter 3. Chapter 4 describes the land use and catchment area characteristics, impacts on other livelihood activities, and LULC conditions in the study sites. The chapter also discusses how human activity, as evidenced by exposure to remote-sensing data, has an impact. Chapter

5, which covers the findings of LULC analyses, comes next. The last chapter offers a synopsis, conclusions, study limitations, and suggestions for additional research.

Conclusion

The study topic was introduced in this chapter. The study's purpose and objectives were made clear, the problem statement was provided in detail, and the study's background was examined. the explanation of terminology and the rationale for the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter aims to review literature related to human activities about land use and land cover changes. The major causes of land use and land cover change impacts shall be discussed. The extent of dynamic changes will be focused on as well as the techniques of investigation such as Machine learning (ML) Remote Sensing (RS) and Geographical Information Systems (GIS). Detecting changes that would have occurred over time will explain the possible future trends as well as predict the likelihood occurrence of disasters related to environmental changes. The dependency of humans on the environment and how they affect it shall be illustrated using a land use land cover change framework.

2.2. Human activities on spatial-temporal LULC change in urban areas

Changes in land use and land cover (LULC) are a major cause of environmental change and are gaining international attention because of their effects on the local, regional, and global environments Human activities including urbanization, deforestation, and population growth exacerbate LULC. The eco-hydrological system of the environment is currently facing challenges as a result of these changes, according to several research.

2.3 Global perspectives

The majority of the planet was a wilderness for a large portion of human history, with forests, meadows, and shrubs dominating its topography. This has drastically changed over the last few centuries: now, half of all livable land is put to use for agriculture. Just 37% of this are left as forests, 11% are made up of bushes and grasslands, 1% are covered in freshwater, and the remaining 1%, which is a far lower portion than people would think, are built-up regions, which comprise towns, cities, villages, highways, and other human infrastructure. Residential, recreational, transportation, and commercial land use have historically made up urban settlements. Most urban settlements evolve over time from primitive to mature (Liyew et al., 2019).

The primary source of urbanization is migration from rural to urban areas, which expands both the size of the urban population and the territory covered by urban areas. Other changes in land usage, economic activity, and culture follow from these population shifts. Population growth, migration, and infrastructure projects all play a significant part in the urbanization process, which turns villages into towns, towns into cities, and cities into metros (Mavhura et al., 2017).

Due to variables affecting urban land use, such as industrialization, trade, commerce location and site, natural resources, housing development policies, transportation routes, playgrounds and entertainment facilities, and government laws, the percentage has increased today (UNFPA, 2015).

More land must be created for public infrastructure, including roads, water facilities, and utilities, housing, and industrial and commercial applications as urban settlements expand due to the growing concentration of people and economic activity (Seto 2019). Ecologists, planners, civil engineers, sociologists, administrators, and legislators are all interested in the multidisciplinary scope of settlement expansion around the world for the sole purpose of determining how much expansion is occurring and how it can be mitigated in terms of its impact on land use and cover (Olewale 2023).

One of the most significant and effective uses of remote sensing and GIS is mapping the growth of metropolitan areas (Jensen 2017). Understanding the evolution of an urban landscape over time has been aided by the analysis of settlement growth using remote sensing data as patterns and processes (Trousdale 2020). Using space-based remote sensors, remote sensing facilitates the acquisition of multi-spatial and temporal data (Ramachandra and Kumar, 2024). Applications of remote sensing that benefit people and society directly and immediately tend to be prioritized. In 2023, Dutta emphasized the benefits of remote sensing. Information about changes in land use and land cover, including where, when, and how quickly they happen, as well as the physical and social processes causing them, is necessary to comprehend how these changes impact and interact with other earth systems. (Ezeobi and others, 2023).

Over the past four to five decades, research on land use and land cover change analysis has been more widespread worldwide. It is widely acknowledged that these studies are essential to national plans for sustainable development. Using remote sensing and GIS techniques, mapping changes in land use and cover is an area of interest that is garnering more and more attention worldwide. Without knowledge of land use, it is challenging to comprehend the importance and possible effects of changes in land cover on the climate, biogeochemistry, or ecological complexity (Ejaro and Abdullahi 2019). Updating land cover maps and managing natural resources require change information (Mirza,javed, and Ain 2022).

Fundamental instruments that can be helpful in the research at the village, district, and city levels are provided by geographic information systems and remote sensing (Rimal, 2022). Statistical analysis, trend analysis, overlay buffering, distance analysis, cost analysis, and many other types of analysis are all included in their analysis (Arimoro et al, 2022).

The use of GIS and remote sensing in land cover investigations has been the subject of numerous studies and publications. Angel et al. conducted a study to look at the dynamics of urban expansion worldwide (2019). By creating a new universe of 3,943 cities with a population of 100,000 or more, and selecting 120 cities at random from this universe to include in a stratified global sample, this study investigated the dynamics of global urban expansion. A number of indicators of the extent and growth of urban areas were determined, including the average density of the built-up area and the built-up area of cities, using population data and satellite photos taken ten years apart (1980–2002).

Globally, settlement expansion has been perceived as a problem of big cities, hence many studies have focused on metropolitan areas (M. G. Munthali et al., 2019).Lin and Liu (2021) noted that due to land use conflicts resulting from the expansion of small service centres, small-town land use and land cover change has become increasingly important in contemporary urban studies.

2.4 Regional Perspectives

Many countries in Sub-Saharan Africa have recently experienced accelerated land use change both in urban and rural as a result of expansion (Athukorala, 2021). According to a 2004 UN report on World Urbanization Prospects, in 1970 there were only 20 million people, or 5 to 10 per cent of the total majority population, living in urban areas in Sub-Saharan Africa. At that time, it was the least urbanized region in the world and, consistent with colonial-era trends, was urbanizing at a slow pace. This scenario changed considerably during the post-independence years. Since the early 1970s, Sub-Saharan Africa had the highest urban growth rate in the world, averaging five per cent per annum (Mavhura et al., 2017) .According to Hopewell and Graham (2014), cities and urban places in Africa represent the fastest-growing sector in sub-Saharan Africa. The UN (2004) noted that by 2030 the extent of urban areas of Sub-Saharan Africa is projected to increase, passing from 7.5% (1950 - 2000) to 22.6% (2000 – 2030). Hopewell further noted that Graham's (2014) urban land cover will increase by 1.2 million square kilometres in 2030.

Rapid urban expansion in many urban centres of Sub-Saharan African countries has been identified as a major cause of land use /land cover change (LULC) (Codjo, 2007, Oyinloye and Adesina, 2006). The use of remote sensing and GIS techniques to monitor settlement expansion is increasingly becoming important in Sub-Saharan Africa (Oyinloye 2019). Zubair (2018) examined the use of GIS and Remote Sensing in mapping land use and land cover in Ilorin, Nigeria between 1972 and 2001 to monitor land cover changes. Muli et al (2017) applied remote sensing and GIS techniques to monitor the spatial growth of Rawangware informal settlement in Kenya between 1990 and 2010. Oyinloye (2019) used GIS and remote sensing to monitor spatial growth of the Federal University of Technology Akure, Nigeria between 1986 and 2012.

2.5 National Perspectives

In Zimbabwe, the proportion of people living in urban areas has increased since Zimbabwe attained independence in 1980 from 26% in 1982, 35% in 2002, 36,8 in 2012 and 40% in 2015 (Murwira 2011, ZIMSTAT 2019). Urban spatial growth in Zimbabwe has been recognized as an agent of land use change by Muronda (2008), Kumashoko et al (2019) and Olewale et al (2003).

Zimbabwe is well endowed with forests and woodlands covering 53 percent of the total land 13 percent is covered by bush lands while 0.3 percent of the area is under commercial plantations. Over a quarter of the woodland area is found on state lands namely National Parks, Wildlife reserves and forest reserves. Zimbabwe is losing an average of 31200 hectares of forest per year according to Forest Commission. However, it is reported that between 200 and 2005 the rate of forest change increased by 16.4% to 1.64% per annum. In total between 1990 and 2005 Zimbabwe lost 21.1% of its forest cover.

Historically loss of land cover is closely related to demographic expansion and the conversion of forest land to other uses. Major direct causes of land cover change brought on by humans include overharvesting of wood for fuel and other forest products. Underlying the causes include poverty population growth market and trade in forest products and macroeconomic policies.

Indigenous forests in Zimbabwe provide a wide range of goods and services that include fruits saw logs medicines honey poles and fuel wood as well as the protection of the environment and maintenance of soil fertility. Because of harsh economic conditions prevailing in the country and the effects of natural disasters like drought most woodland is under severe utilization pressure. These ecosystems in the dry parts are fragile and overuse of the vegetation resource results in the formation of bare sites and general loss of vegetation cover.

In Zimbabwe, the land cover area designated for production also declined from 2,216,000 ha in 1990 to 1,406,000 ha in 2015 (Chigumira et al. 2019). In Zimbabwe, both public and privately owned land cover has been declining over time with biomass falling from 1483 million tonnes to 941 million tonnes. According to the Convention on Biological Diversity, increased land cover degradation and destruction is due to several factors, with the major factor being human activities such as the collection of non-timber forest products for medicinal purposes, commercial timber and tobacco curing (Government of Zimbabwe 2020). Discussions with stakeholders revealed that forest diversity has been declining at an average annual rate of 330,000 ha and this is due to expansion of agriculture, infrastructural developments, mining, invasive alien species and climate change (Government of Zimbabwe 2020).

The depletion of forest cover is going at a higher rate than the current planned tree planting rate. Approximately, about 60 million trees are lost a year and 15 million trees are planted a year. Additionally, about 90% of farmers use wood fuel to cure tobacco and this has caused 15% of forest cover to be lost by 2015 (Chigumira et al. 2019). Forest cover loss is rapidly increasing as more and more farmers are increasingly growing tobacco on an annual basis. Rapid population growth has increased clearance of forests for cultivation (Chigumira et al. 2019).

The increase in mining activities due to recent discoveries of gold, diamonds, gold and copper has resulted in massive clearance of forests as new mines are developing whilst old mines are expanding. To add, more than a million people are panning gold illegally which has led to the clearing of trees. In 2017, Zimbabwe's population was estimated to be 16.5 million with an annual growth rate of 2.3% and as a result of economic hardships, there has been increased pressure on forest resources as people turn to use it as an alternative source of their livelihood (Chigumira et al. 2019).

Studies on settlement spatial growth using remote sensing and GIS techniques in Zimbabwe have focused on the Harare metropolitan urban area only. Olewale et al (2018) used remote sensing and GIS techniques to monitor Harare's urban expansion between 1976 and 2002. The study revealed a loss of about 1.38% of farmland to urbanization between 1976 and 2000. Kumashoko et al (2019) did a similar study in Harare between 1984 and 2019. Results revealed that built-up areas increased from 12.6% to 36.3% of the total land area, while non-built-up cover decreased from 87.3% to 63.4% between 1984 and 2019.

Chigara (2019) noted that piecemeal planning has been shaping spatial development such as infrastructure and housing in Zimbabwean small towns without a detailed and comprehensive attempt to determine, keep track of, and evaluate their status. Piecemeal planning is reactionary planning that often results from development pressures that are translated into development needs by creating a multiplicity of micro layout plans to cater for development initiatives like housing (Liyew et al., 2019).

2.6 Land Use Changes in Local Council Areas

Land use refers to the activities being carried out on the land, showing the current use of the land resource (Mavhura et al., 2017). Land uses differ from place to place as land is not uniform (Koranteng et al. 2021). In communal areas, land was mainly used for subsistence and small-scale commercial farming. Due to technological advancement, population growth, industrialization and globalization land use changes have become rapid in communal lands as they are seen as a way for economic development and social progress (Biswas 2018). Therefore, the use of land in communal areas has changed from being used for subsistence and small-scale commercial farming into, settlement planning and industrial areas to improve income and the standards of living. In Mashonaland Central Province in Bindura district, the Bindura Urban town is a good example of where indigenous forests have been cleared as a result of land use changes. Continuous land use changes in Bindura Urban need to be detected using GIS and RS techniques to know the extent to which these changes are affecting forested areas.

2.7 The techniques used to detect changes over time

Change Detection is defined as a process to identifying significant differences in sequential pixel appearances due to the emergence, disappearance, movement or shape alteration of objects (Panuju, Paull, and Gri 2020). For the past years, several methods have been developed for change detection. These methods include algebra, classification, transformation, visual analysis, GIS and RS (Liyew et al., 2019). A brief explanation of the methods used in change detection will be given below.

2.7.1 Remote Sensing

Remote sensing has become an important tool applicable to developing and understanding the global processes affecting the Earth (Mallupattu, Reddy, and Reddy 2019). Remote Sensing is an advanced technic that does not require physical contact with objects since satellites are used to collect data. Remote sensing has three stages involved and these are collecting information from satellites, and analysing and interpreting the information which leads to the generation of maps (Mazorodze et al, 2018). The development made in the use of satellite data was to assist in the interpretation of the geographical data available (Mallupattu 2019).

2.7.2 Geographical Information System

In order to facilitate development-oriented management and decision-making processes, GIS is an integrated system of computer hardware and software that may be used to capture, save, retrieve, manipulate, analyze, and display geographically related information (Mallupattu, Reddy, and Reddy 2019). A digitizer, Global Positioning System (GPS), network, plotter, CD-ROM drive, and most crucially, a computer are essential instruments for enhancing the effectiveness of GIS implementation (Mazorodze et al., 2019).

2.7.3 Algebra

Image differencing, image regression, image rationing, vegetation index differencing, change vector analysis (CVA), and background subtraction are all included in this change detection technique. The selection of thresholds to identify the altered areas is a common feature of these change detection algorithms (Corresponding et al. 2020). With the exception of change vector analysis, all algebraic procedures are rather basic, uncomplicated, and simple to apply and understand; yet, they are unable to provide comprehensive change information matrices (Chen et al., 2003)Image differencing is conceptually expanded upon by change vector analysis. All changes larger than the defined thresholds can be found using the change vector analysis approach, which can also offer comprehensive change information. The challenge of choosing appropriate thresholds to identify the altered areas is the algebra category's drawback. Two factors in algebra are essential to the outcomes of the change detection process. In order to identify the altered areas, this entails choosing appropriate thresholds and picture bands or vegetation indices (Corresponding et al. 2020).

2.7.4 Transformation

In addition, this method of change detection includes Principle Component Analysis, Kauth Thomas transformations, Gramm–Schmidt (GS), and Chi-square transformations (Corresponding et al. 2020). One advantage of these methods is in reducing data redundancy between bands and emphasizing different information in derived components. However, they cannot provide detailed change matrices and require a selection of thresholds to identify changed areas (Hussain et al. 2019). Another disadvantage is the difficulty in interpreting and labelling the change information on the transformed images (Corresponding et al. 2020).

2.7.5 Classification

This method of change detection includes post-classification comparison, spectral–temporal combined analysis, expectation–maximization algorithm change, unsupervised change detection, and hybrid change detection (Ezeobi et al., 2023). The methods of classification are based on the classified images, in which the quality and quantity of data are important to produce good-quality classification results. According to Li and Yeh in 1998, multi-temporal images combined with supervised maximum likelihood classification can effectively monitor urban land-use change (Almarri, 2023)Silipaswan in 2001 used unsupervised classification and visual interpretation of aerial photographs to detect land-cover change and found that the combination of Change Vector Analysis (CVA) and unsupervised classification provided a more powerful interpretation of change. The major advantage of classification methods is that they have the capability of providing a medium of change information and reducing external impact from atmospheric and environmental differences between the multi-temporal images (Neasa, Mallie, and Gemeda 2020). However, selecting high-quality and sufficiently numerous training sample sets for image classification is often difficult, in particularly for historical image data classification. The method of classification is usually time-consuming and difficult to produce accurate classifications leading to unsatisfactory change detection results (Kamusoko and Aniya 2018)

2.7.6 Visual Analysis

Moreover, onscreen digitization of altered areas and multi-temporal picture composite interpretation are part of this change detection technique. The texture, shape, size, and patterns of the image are important components that are helpful for visually interpreting changes in land use and land cover (Hussain et al. 2019). A proficient analyst is the only one who can put together all the relevant information needed to make choices regarding changes to land cover and use. In visual interpretation, it is challenging to isolate an image's constituent pieces. For bigger areas, this approach takes longer, and regular updates on the changes are challenging. This approach was formerly employed in situations where digital data was unavailable and computer storage capacity was inadequate. Visual interpretation was gradually superseded by distant sensing techniques and rapid advancements in computer technology (Corresponding et al. 2019).

2.8 Drivers of land use changes

The land is an important base on which all human activities are done. It provides raw materials needed for all the activities to be carried out (Araya and Cabral 2018). The use of land resources to meet the needs and wants of humans has given rise to a variety of land uses causing land use changes to occur in different regions (Araya and Cabral 2018). The drivers of land use change are biophysical socio-economic drivers.

2.8.1 Biophysical drivers

Biophysical drivers indirectly cause land use changes since they cause land-cover change which influence the decisions of land uses by land owners and managers (Deng et al. 2019). These factors include weather and climate, geomorphic processes, soil fertility and type and the availability of resources.

2.8.2 Economic and technological drivers

Policies influence land use changes by changing prices, taxes, change cost of production, investments, trade, technology and capital flows. Due to differences in wealth between households, land use changes have only been possible for those who can develop, use and profit from the changes in land use. The availability of loans, cheap fertilizers, market and improved technology has encouraged forests to be converted into other land uses such as croplands, settlements, industry and mining (Stillwell, 2021).

2.8.3 Demographic drivers

An increase or decrease in population size has an impact on land use changes. Increases in fertility and mortality influence household structures. This is because the number of people per household will determine the size of land needed for agriculture and settlement. The larger the size of the household the larger the land needed by families extending into multiple nuclear families. Migration is the most important demographic factor causing land use changes since it leads to rapid population growth. The growth of urban-rural population distribution and rapid urban expansion are important factors that have led to land use changes (Zondag 2019).

2.8.4 Institutional drivers

Political, legal, economic and traditional institutions affect land use changes. The access to land, labour, capital, technology and information is structured by local and national institutions and policies. This includes property rights, environmental policies and institutions, and social networks concerning distribution and access to resources. Institutional controls over land use are changing from local to regional and global levels. Ownership of land has led to rapid land use changes (Dampha, 2021).

2.8.5 Cultural drivers

Decisions about land use changes made by land managers are influenced by personal histories, attitudes, beliefs, collective memories and individual perceptions. The positive and negative environmental effects of land use changes depend on the management skills, knowledge and information available to land managers. Decisions of land use changes made by land managers are usually due to economic and political conditions. Cultural models of land managers help to explain adaptive strategies, resistance to policies and social resilience to land use change (Marondedze and Schütt, 2019).

2.9 Impact of human activities on land use changes

Land use changes have occurred due to economic activities such as mining, agricultural production and industrialization meant to alleviate hunger and poverty to improve the livelihoods of people (Wu 2018). Intensified agricultural production leads to high yields of crops. Selling of surplus crops helps to generate income. Industrialization and mining result in the development of infrastructure. This includes the development of schools, hospitals, roads and other recreational facilities. Land use changes have led to the construction of roads. This makes other areas further away from towns and cities to be accessible promoting the transfer of technology and information. Land use changes have improved the social networks of people as there is the diffusion of ideas from one place to the other (Wu 2018).

2.10 Negative effects of land use changes

2.10.1 Global warming and climate change

Clearing of forested areas to do agriculture, mining and industrialisation results in the removal of vegetation which acts as a carbon sinker. Continuous release of gases such as carbon and methane from industry, mining and agriculture will lead to the creation of a blanket-like layer in the atmosphere. This layer prevents heat from being released back to space and this will create warm conditions on the earth's surface known as global warming. With time, gases such as methane and carbon will destroy the ozone layer. This will pave the way for the entrance of ultraviolet raises to the earth's surface causing climate change (Implications et al. 2018).

2.10.2 Floods, erosion and siltation of rivers

Land use changes have led to the clearance of forested areas exposing the ground to agents of erosion wind and water. Due to the absence of roots to bind the soil, tree leaves and branches to reduce raindrop velocity and leaf litter to cover the soil, erosion has become high in deforested areas (Chiwera 2017). Exposure of bare land to heat has led to soil compaction. When rains fall it is difficult for the rain to infiltrate leading to quick generation of overland flow. The development of concrete surfaces will prevent infiltration leading to quick generation of overland flow causing floods to occur (Athukorala, 2021). Continuous flooding results in massive loss of topsoil. The eroded sediments are deposited in water bodies. With time the depth of water bodies is reduced until the rivers are filled with sediments and no longer able to hold water as a result of siltation (Berg et al. 2019).

2.10.3 Eutrophication of water bodies

Eutrophication refers to the excessive accumulation of nutrients in water bodies (Dube, Gumindoga, and Chawira 2019). Removal of forested areas to expand agricultural activities has paved the way for eutrophication in water bodies. Fertilizers are eroded and deposited into rivers and dames increasing the level of nutrients in water. A steady accumulation of nutrients in water bodies has resulted in extensive growths of surface-floating aquatic weeds in freshwater. This has caused a decrease in biodiversity, threatening critical habitats of aquatic animals, altering nutrient cycles and degrading water quality (Dube, Gumindoga, and Chawira 2019).

2.11 Land use change theory

For this study, a land use and land cover Framework shall be used. This framework explains the elements and processes causing land use and land cover changes generated as a result of the interactions between social and environmental subsystems. The theory consists of exogenous and endogenous initial causes that affect the demand for environmental services which eventually affect environmental conditions and dynamics. The elements of the framework show all variables necessary to explain land systems. The arrows connecting variables show a relationship among variables. The focus is on the demand for land by land users and the changes that are resulting from the change in land use. The socio or political-economic structures that are also actors in land use change are identified in the framework. The framework also links previous land uses with how they affect the availability of environmental services, technological management strategies and infrastructure. Land use changes occurring in Bindura due to high demand for land caused by rapid population growth, development of land ownership rights and policies and laws put in place by the government making the change in land use possible. Improved technology has enabled people to engage in a variety of land uses which has affected the availability of environmental services leading to changes in environmental conditions.

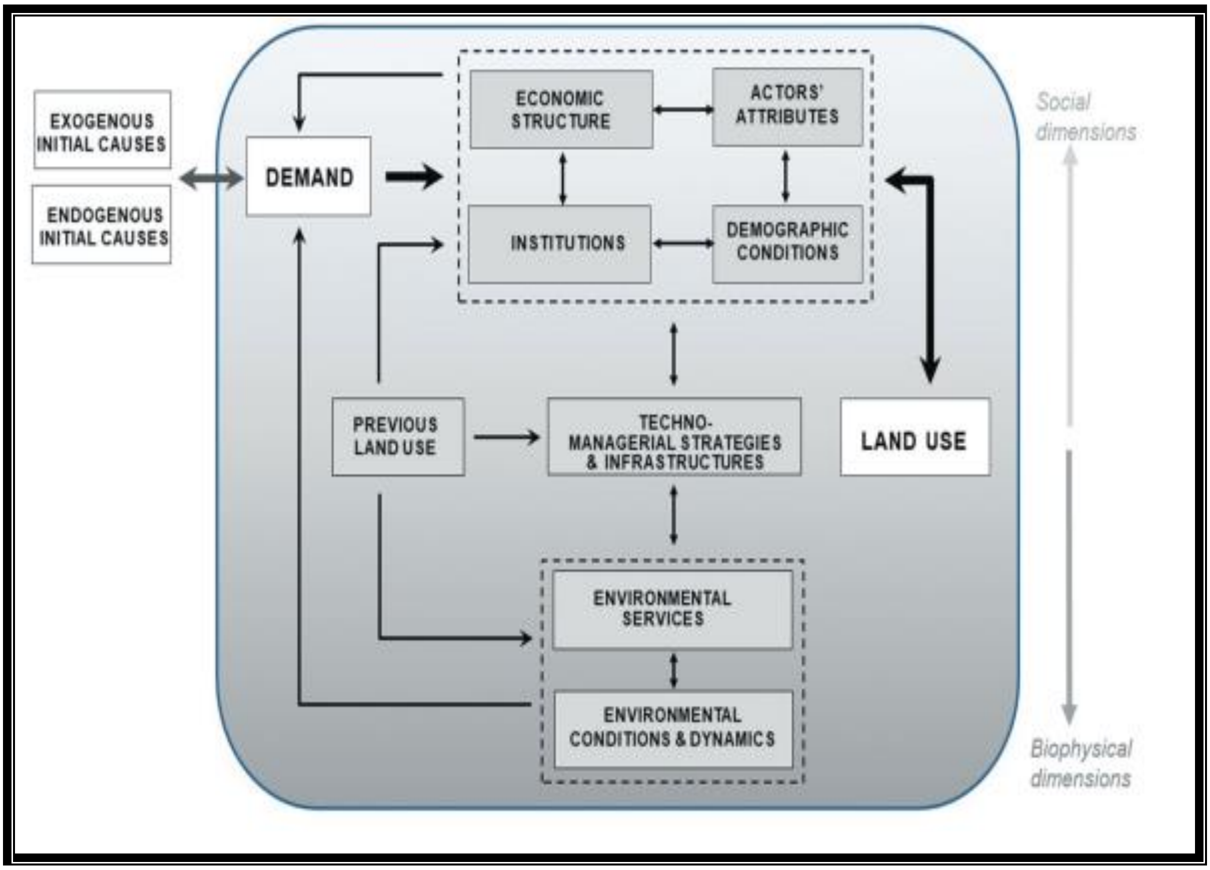

Figure 2.1 Land use Land Cover Framework

2.12 Research gap

The research done by Kamusoko and Aniya in 2018 focused on fast fast-track land reform program and how it affected forest cover. The permanent clearing of forests by the black majority to develop croplands and settlements was explained. Additionally, in 2019, Mufari carried out research in Masembura focusing on tobacco farming and how it has affected nearby forests. The extent of land use changes occurring in Bindura District and their impacts on nearby areas has never been researched. A better understanding of how Bindura as a district has been affected by land use changes will help to understand how human activities have brought change over time as well as predict the effects of this change in land use and land cover over time to improve the disaster preparedness plan of the district and the early warning systems(Noor et al., 2021).

2.13 Summary

The chapter provided an overview of literature based on land use and land cover changes. The trends and dynamics of land cover and land use in Zimbabwe were outlined. The drivers of land use land cover changes were discussed along with the effects caused by change in land uses. The techniques and methods of change detection were discussed. A theoretical framework that explains the interdependency of various variables necessary in land systems and how they cause change in the environment was used in this chapter to better explain land use land cover changes in Bindura District.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

This chapter Methodology adopted in this study consists of three major components: data collection, image classification and land cover change analysis. The research conducted in this study was divided into four main stages within the adopted research procedure.

3.2 Study Area

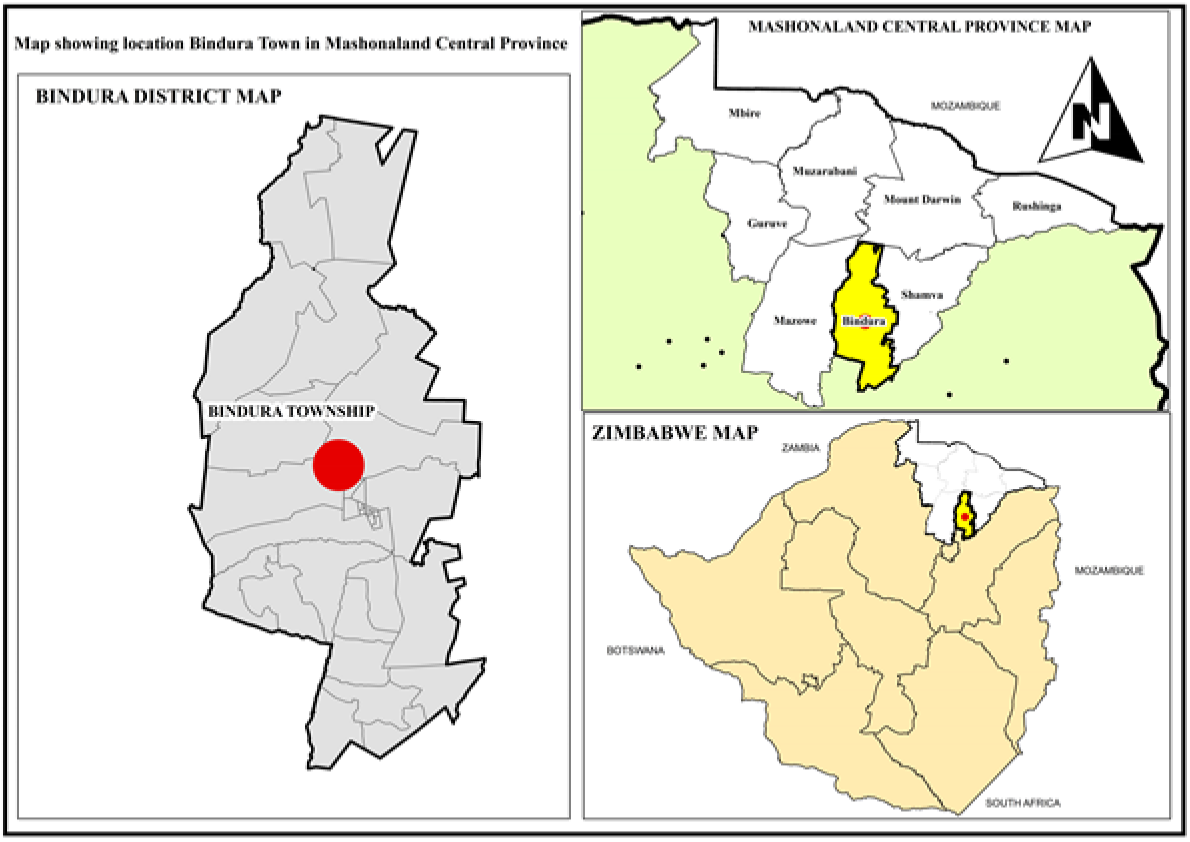

Figure 2.1: Study area map for Bindura District

The Mashonaland Central Provincial Capital, Bindura District, served as the site of this study. It is situated 89km North-East of Harare between Mt Darwin, Mazoe and Shamva District. The district is located within the Mazoe Valley. The district lies in ecological Region 2 and is the provincial capital of Mashonaland Central Province. The coordinates of Bindura district, Zimbabwe are 20°56'20.0"S, 29°01'07.0" E (Latitude: -20.938889; Longitude: 29.018611). Bindura district is sitting on an average elevation of 1,070m above mean sea level. The area falls into Region IV of Zimbabwe’s driest areas characterized by relatively high rainfalls predominantly in summer between November and March (Gabela 2019). For the greater part of the year, hot dry weather is experienced for example July to October with cold spells from

May to June. The temperature average is 28℃ during the hot summer season and +/-17℃ in winter (Hassan & Syakir, 2023).According to the 2022 ZimStat Census Population Census, the town had a population of 50,400 and a total of more than 10200 households. The economic activities revolve around farming and mining of gold as well as a sound livestock production area. Due to activities, the district has been developing and growing in terms of population. Due to their proximity to the Mazowe River, the main sources of income are market gardening, artisanal mining, and subsistence farming.

3.3 Research Design

A randomised complete block design was used to do this research. Experiments were done during the processing of Landsat images which were downloaded from USGS. The Landsat images used were for the years 2015, 2018 and 2021(Gondwe et al., 2021). These images were classified and used to calculate the magnitude change of six classified land uses in Bindura. The images were analysed using change detection methods (Supervised Classification). Magnitude change and percentage change were calculated using a field calculator in QGIS. Surveys were done using a questionnaire and both qualitative and quantitative data in Bindura. Ten per cent of respondents were randomly selected using calculator-generated random numbers. Quantitative data were analysed using frequency tables and bar graphs. Qualitative data were analysed manually by categorising common ideas based on people's feelings and opinions (Farjana and Selim, 2022).

3.4 Data Acquisition

During this excuse, a Global Positioning System (GPS) application was used called GPS status. Point data was collected for ground truth and delimitation of the study area. Five points were taken for each land use class and were collected for training during supervised classification. The collected points were used for training during classification and for accuracy assessment of the satellite images (Silva et al. 2022).

3.4.1 Acquisition of Satellite Images

The period of the study is from 2002 to 2022; with a targeted 10-year interval Landsat 5 (TM) images were used to assess the Spatial-temporal Analysis of Human Activities on Land Use / Land Cover Changes in Bindura Urban Area Using GIS and Remote Sensing. The used Landsat images path row of 169/072 and a high spatial resolution of 30 m by 30 m. These images were downloaded from the United States Geography Survey (USGS) for ten years' intervals between 2002, 2012 and 2022. Table 3.1 below shows the used Landsat images and the Sentinel there.

3.4.2 Image Pre-processing and Processing

Remote sensing image pre-processing and processing are critical steps in extracting useful information from remote sensing data. Pre-processing involves a series of steps to enhance the quality of the raw imagery, while processing involves analysing and manipulating the pre-processed data to extract meaningful information (Aditya 2021).The data in use will be typically acquired from satellites, (Landsat 8-9). The data is collected in the form of digital images, which can include various spectral bands (e.g., visible, infrared) and different resolutions.

The pre-processing process involves radiometric calibration corrects for sensor-specific biases and converts the raw digital numbers in the image to physical units of radiance or reflectance. Geometric correction rectifies geometric distortions caused by sensor tilt, terrain relief, and Earth's curvature. Atmospheric correction compensates for the effects of the atmosphere on the remote sensing data ((Journal & Sensing, 2020). It removes atmospheric scattering and absorption, thereby improving the accuracy of the surface reflectance values. Image enhancement techniques are applied to improve the visual quality of the image and highlight specific features of interest. Examples include contrast stretching, histogram equalization, and filtering operations like sharpening or smoothing (Albalawi et al., 2018).

Change detection techniques compare multiple images acquired at different times to identify and quantify changes that have occurred in the study area. It can be useful for monitoring land cover changes, urban growth, and environmental impacts. Image fusion combines data from multiple sources or sensors to create a composite image that contains richer and more detailed information. Fusion techniques can integrate different spectral bands, resolutions, or sensor types to generate a more comprehensive representation of the scene (Journal & Sensing, 2020).

3.5 Data Analysis

The pre-processed imagery can be subjected to various analysis techniques, such as Image classification with future extraction, pattern recognition, object detection, and spatial modelling. These techniques enable the extraction of specific information or measurements from the remote sensing data.

3.6 Spatial Modelling Techniques

3.6.1 Sequences of instructions in Image Classification

To perform supervised classification on Landsat 8 pictures for the years 2002, 2012, and 2022, use the Semi-Automatic Classification Plugin of QGIS 3.20.3. The technique of classifying pixels or segments of images into preset sections or categories according to their spectral features is known as image classification. Both supervised and unsupervised classification techniques can be used for it. The process of categorization makes it easier to identify different types of land cover, objects, or other features in a picture. It picks homogeneous data by choosing pixels with comparable spectra (Athukorala, 2021). Maximum likelihood classification is the most used algorithm for classifying land uses, hence it can be used to perform supervised classification. The findings are classified through ground trothing, which is a benefit of utilizing maximum likelihood classification (Liyew et al., 2019).

3.6.2 Random Forest

Regression and classification are two applications for the machine learning algorithm Random Forest (RF). Combining different tree predictors into a single random vector that is separately sampled and has the same distribution for all the trees in the forest creates a random forest (RF) (Tian, Zhang, Tian & Sun, 2016). An ML classification technique made up of several choices trees is called the RF. It is an ensemble learning technique that creates predictions by combining several decision trees. An ensemble of decision trees makes up Random Forest. A random subset of the input features and a random portion of the training data are used to separately build each decision tree. The model performs better and less overfitting occurs thanks to this randomness Selection of features at random A random subset of features is taken into consideration for splitting at each decision tree node. By selecting features at random, the forest's trees are kept from being unduly connected and a wide range of forecasts are produced (Mirza, Javed, Mayo, and Ain 2010–2022).

3.7 Image Pre-processing

An essential phase in the satellite image processing process is picture pre-processing. Because satellite photos are captured from extremely far locations, there are a lot of noise, distortion, and mistakes in the data recording and transmission processes. Pre-processing usually consists of picture sub-setting, image mosaicking, image enhancement, geometric correction, and radiometric correction. To extract meaningful information from the photos, pre-processing must be done on at least one or more of the processes. In this work, we perform geometric rectification, picture augmentation, and image mosaicking on photos that are utilized for classifying land cover.

3.8 Post-Processing

An image that has been post-classified processed may be smoother. The post-classification techniques commonly used in Erdas include clumping, sieving, eliminating, and recoding. More precisely, clumping is a method of creating an output image by figuring out how big each sorted region is and then storing the categorized value of the biggest neighboring pattern. After clumping, the isolated small spots can be dissolved by sieving, which gives the small spots new values. In clumped or classed photos, eliminating is used to dissolve isolated little areas; these small spots are then combined into the largest neighboring class (Zhu, 2019). One method of reassigning each category's class code is recoding.

3.9 Accuracy assessment

The comparison of classified maps and what exists on the ground (Mukwenyi, 2017). To make the results obtained from Landsat images trustworthy for use, an assessment of accuracy was done. GPS points were used to do an accuracy assessment. During ground truthing in Bindura district, GPS points of land use classified on Landsat images were collected and recorded. Using Google Earth Explorer GPS points were used to identify the classified land use. When the loaded GPS points appeared on the exact land use identified on Landsat images, shape files were created and imported to QGIS. The shape files created in Google Earth Explorer using GPS points were used for true and false colour composition. When doing true and false colour composition the GPS points helped to locate the exact land use to make the classification more accurate for use. The error matrix was also used to do an accuracy assessment. The error matrix columns represent referenced data and the rows represent classified data. The number of pixels for each land use on classified images was counted and recorded in columns on the error matrix. The number of pixels for each land use on actual pictures converted into a raster was counted and recorded in rows on the error matrix. To create an error matrix for accuracy assessment three equations below were used (Canada n.d.).

$$User\ Accuracy\ = \frac{A}{B} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (1)$$

Where A = the number of pixels classified in both data sets for each land use; B = the total number of pixels in each selected row.

$$\textit{Producer Accuracy} = \frac{A}{B} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where A = the number of pixels classified in each data set for each land use; B = the total number of pixels in each selected row.

$$\textit{Total Accuracy} = \frac{A}{B} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where A = the total number of pixels classified for all land uses in both data sets; B = Total number of all pixels identified in all data sets.

3.10 Conclusion

The study area and the research strategy were all covered in this chapter. This chapter also focused on the methods or techniques used to get the data preparation to analyse it. This chapter also described how the study's data were gathered and what ethical issues had to be taken into account. The methods utilized for presenting and analysing the data from the research sample in the following chapter are also highlighted in this chapter.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents the results and discussion of the findings from data analysis. The data analysis presented in the previous chapter provides a strong basis for responding to the research. Spatial-temporal analysis of human activities on land use / land cover changes in Bindura District between 2002, 2012 and 2022 using QGIS and remote sensing technique called supervised classification. The results will be presented in form of classified Landsat images and tables as well as NDVI images. Percentage change and magnitudes of change in the land use classes will be quantified using cross-tabulation matrix tables while visual interpretation will be adopted to interpret changes in land degradation

4.2 False colour composition maps for Bindura District Landsat Images (2002, 2012 and 2022)

The Landsat Images were first transformed into false colour composites using the Semi-Automatic Classification (SCP) to allow smooth classification of images into different land-uses. Figure 4.1 illustrates the false colour maps of the three datasets.

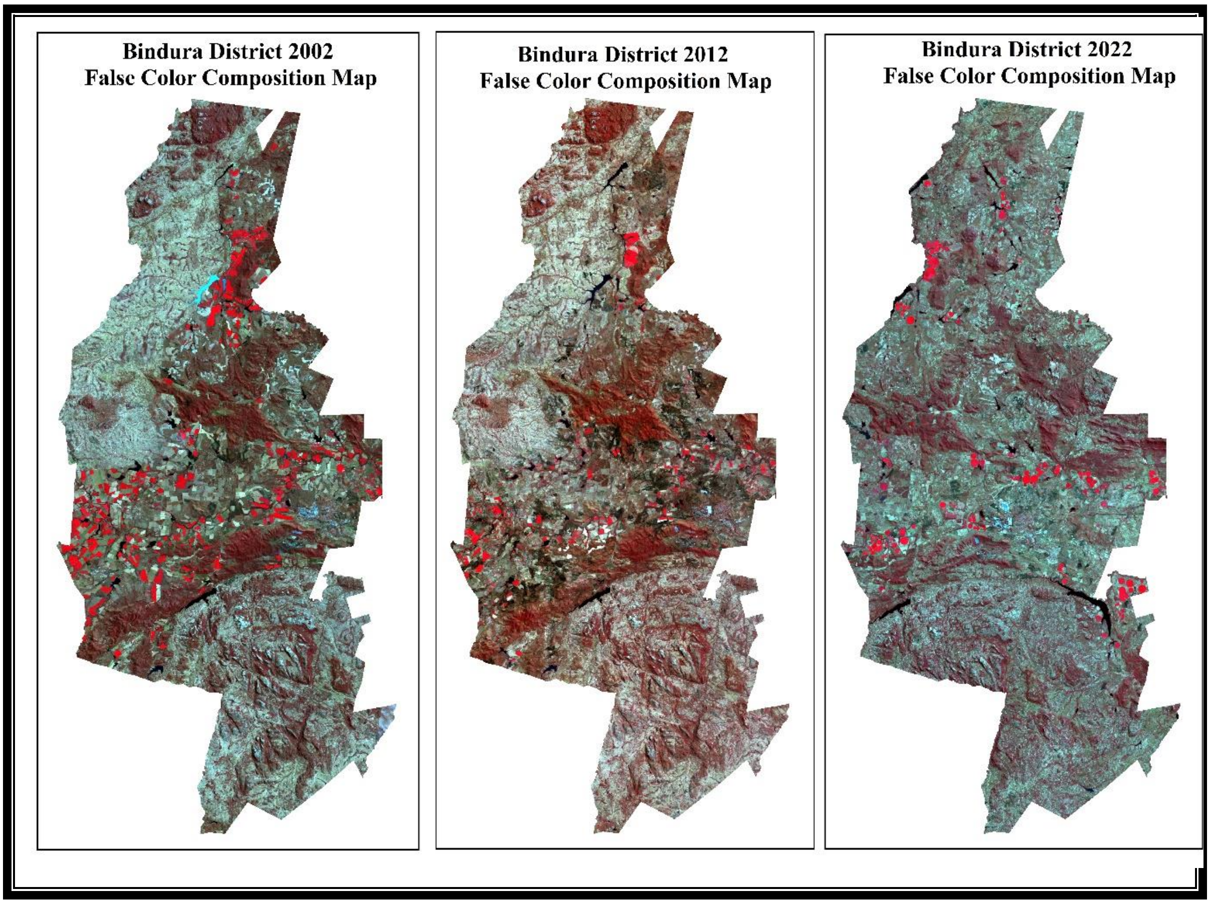

Figure 4:1 False colour composition Map (Images produced by the author)

4.3 Land-use-land cover classification in Bindura District

4.3.1 Land Cover Classification Color codes

The study area has been defined to have five land cover categories. The land cover classification is shown in table below:

Land Cover Class	Color Code
Buildup Area	
Water	
Bare ground	

Cultivated Area mixed with Ploughed Land	
Agriculture Fields	
Mountain and Rock Area	
Vegetation	

Table 4.1 Land Cover Classes

Buildup Area-Color Code: Red

Buildup areas in Bindura District represent urban and residential areas with a concentration of buildings, infrastructure, and human settlements. High population density, commercial activities, and residential developments characterize these areas.

Water Color Code: Blue

Water bodies in Bindura District include rivers and dams. These areas provide important water resources for irrigation, drinking water, and supporting aquatic ecosystems. They are vital for agriculture, wildlife, and recreational activities.

Bare ground - Color Code: Yellow

Bare ground areas in Bindura District consist of exposed soil or rock surfaces with minimal vegetation cover. These areas may occur naturally in arid or semi-arid regions or as a result of land degradation due to human activities such as mining or deforestation.

Cultivated Area mixed with Ploughed Land - Color Code: light Green

Cultivated areas in Bindura District are used for agriculture and farming purposes. These areas include crop fields, orchards, and plantations where various crops are grown, such as maize, wheat, tobacco, and vegetables. Agriculture plays a significant role in the district's economy.

Mountain Area - Color Code: Gray

Mountain areas in Bindura District are characterized by elevated terrain, steep slopes, and rugged landscapes. These areas are often covered with forests, grasslands, or shrubs. They provide important habitats for biodiversity, scenic beauty, and recreational opportunities.

Vegetation- Color Code: Light Green

Vegetation areas in Bindura District consist of natural or semi-natural ecosystems, including forests, woodlands, grasslands, and wetlands. These areas support diverse flora and fauna, provide ecosystem services, and contribute to climate regulation and water resources.

4.3.2 Land-Use-Land-Cover Classification Output

The images were categorised into the land uses stated in the previous section 4.3.1. The supervised classification outputs allowed clear visualization of the varied land-uses within Bindura District. Figure 4.2 summarizes the supervised classification output for LULC in Bindura District.

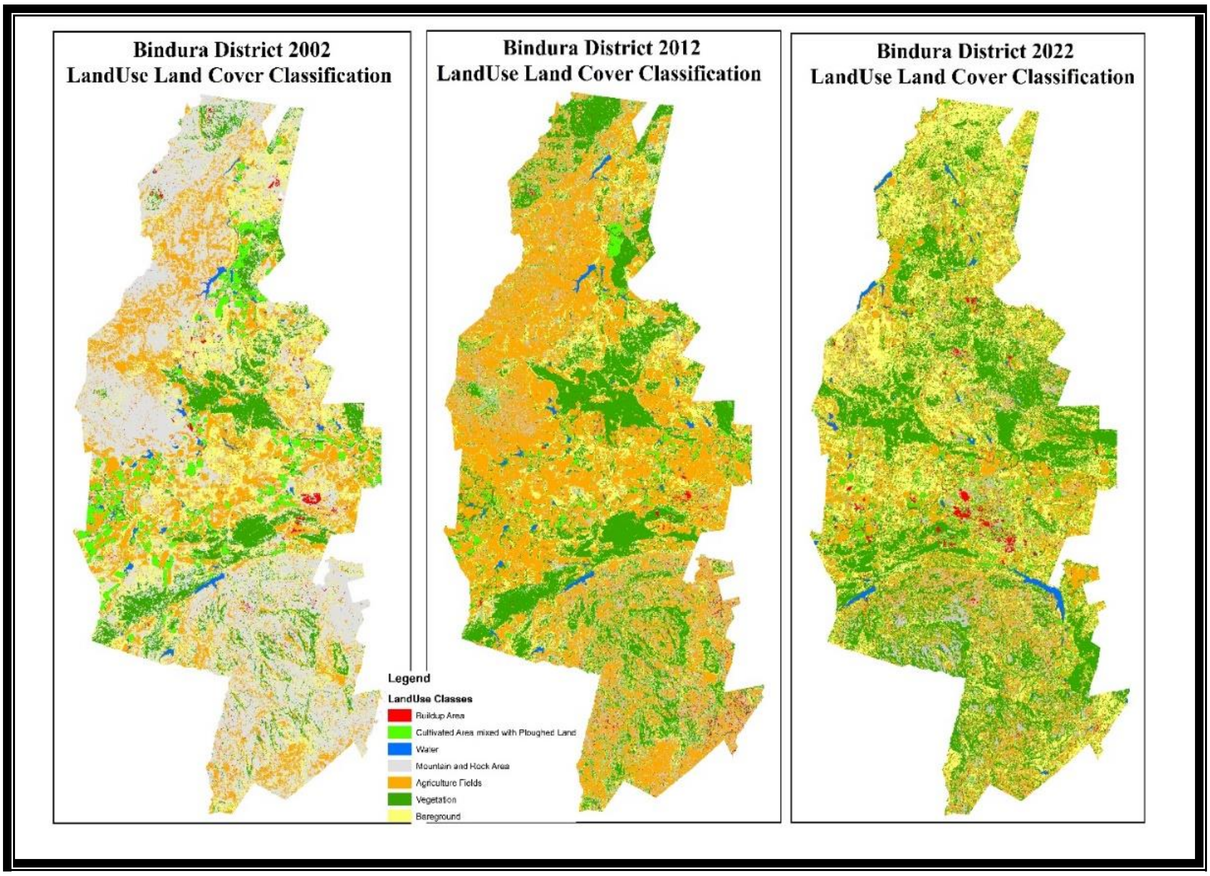

Figure 4:2 Land Use Land Cover Change Map for Bindura District

Figure 4.2 offered a clear picture of the LULC categories in Bindura District. Summaries of the areas covered by each LU or LC were presented in table 4.2.

Class	**2002**		**2012**		**2022**	
	Ha	**% Area**	**Ha**	**% Area**	**Ha**	**% Area**
Water	7174.4	3.7077	5399.9466	2.40854	7177.314	3.2013
Mountain Area	24549.9	11.6739	19089.688	8.51458	15315.774	6.8313
Cultivation	49099.8	21.8413	36957.576	16.4842	37489.154	16.7213
Bare ground	31836.4	14.9732	23441.006	10.4554	30720.556	13.7023
Vegetation	41477	19.1489	49539.680	22.0962	53160.734	23.7113

Agriculture Area	53920.1	20.7499	69444.559	30.97438	55447.574	24.7313
Buildup Area	16142.4	7.9051	20327.541	9.0667	24889.114	11.1013
Total	224200	100	224200	100	224200	100

Table 4.2 Land Cover area covered by each LULC for Bindura District (2002-2022)

The land cover area of water remained relatively stable over the years, with a slight increase in 2022 compared to 2002. The land cover area of mountain areas decreased consistently from 2002 to 2022. The land cover area of cultivation showed a slight decrease from 2002 to 2012 but increased again by 2022. The land cover area of bare ground showed a slight decrease from 2002 to 2012 but increased again by 2022. The land cover area of vegetation increased consistently from 2002 to 2022. The land cover area of agriculture showed a significant increase from 2002 to 2012 but decreased slightly by 2022. The land cover area of built-up areas showed a consistent increase from 2002 to 2022.

The stable land cover area of water indicates that there haven't been significant changes in the district's water bodies over the years. This could be due to the presence of natural water sources such as rivers, lakes, or reservoirs. The decrease in the land cover area of mountain areas suggests potential changes in the topography of the district. It could be due to factors like erosion, deforestation, or land-use changes. Further analysis would be necessary to determine the exact causes. The slight decrease in the land cover area of cultivation from 2002 to 2012 could be attributed to factors like urbanization or changes in agricultural practices. However, the subsequent increase by 2022 indicates a resurgence in agricultural activities in the district. The fluctuation in the land cover area of bare ground indicates changes in soil erosion, land degradation, or land-use practices. The increase by 2022 could be due to factors like deforestation or land clearing for various purposes. The consistent increase in the land cover area of vegetation suggests positive changes in the district's natural environment. It could be a result of reforestation efforts, natural regeneration, or improved land management practices. The significant increase in the land cover area of agriculture from 2002 to 2012 indicates expansion in agricultural activities in the district. The subsequent slight decrease by 2022 could be attributed to factors like changes in agricultural practices or land-use diversification.The consistent increase in the land cover area of built-up areas reflects urbanization and infrastructure development in Bindura District. This could be a result of population growth, economic activities, or urban expansion.

4.4 Trends of Homogeneous Land Use and Land Cover over the Years

4.4.1 Changes in Agricultural Land-use

Changes in agricultural land use were analysed to determine whether there were positive or negative changes in this Land-use type. Figure 4.3 shows changes in agricultural area's land use cover over the three different years being compared. This is meant to determine the land use change trends and the human activities that contributed to these changes, as well as the associated impacts on humans, livelihoods and the environment.

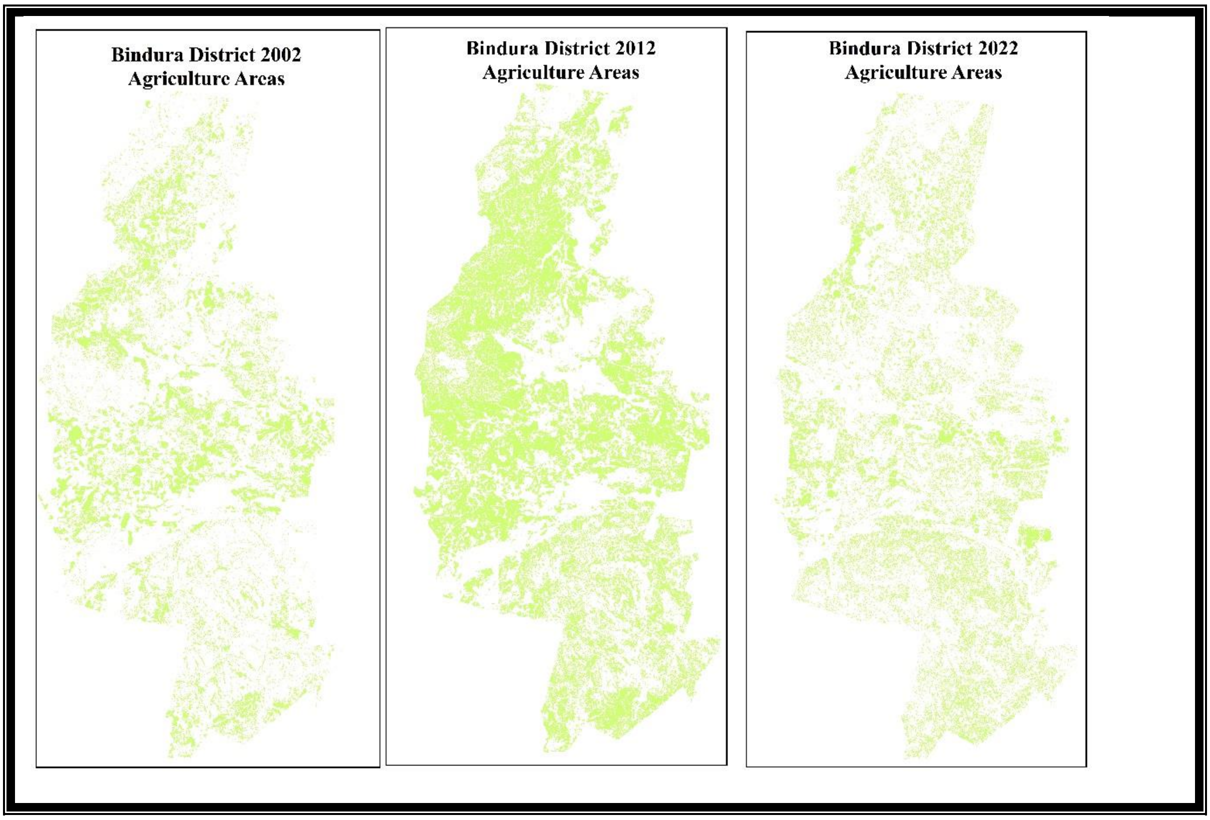

Figure 4:3 Agriculture Planted Land Use

The fig visualizes the changes in agricultural areas for the three years in question. The fig shows that there was a significant increase in agriculture areas from 2002 to 2012 which was then followed by a significant decrease in 2022. The change was then quantified by calculating the number of pixels covered to determine the area covered by agriculture land use and its percentage in relation to the total are of the district. The Table below shows this:

Agriculture Area			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	**53920.1 Ha**	**(20.75%)**	(00.00)
2012	**69444.56 Ha**	**(30.97%)**	(+10.22)
2022	**44920.3 Ha**	**(19.37%)**	**(-11.6)**

Table 4.3 Area Covered by Agriculture land Use

The results of this research show an increase in agriculture areas from 2002 to 2012, (from 20.75% to 30.97%, respectively). The increase was a result of the intensification of agriculture by the newly resettled farmers which cause the conversion of grasslands and tree vegetated areas into crop farming areas, (Wu 2018). This have significantly contributed to food security of the nation in that period, thus the majority of the rural citizens derived their livelihood from crop farming. This was sustainable considering that the cost of inputs was considerably affordable and the district was receiving normal to above normal rains which were evenly distributed throughout the plant growing season. However, the period from 2012 to 2022 saw a decrease in the total area covered by agricultural land use. Thus the results of this research differ from the one that was done by Liyew et al, (2019) which found that half of the habitable land is used for agriculture. This therefore implies that in Bindura District people are diverting from crop farming as a result of the increase in the frequency and intensity of drought as well as mid-season dry spells caused by climate change, (Chiwera, 2017).

4.4.2 Bare ground land Cover

Fig 4.4 below shows bare ground land cover change over time from 2002 to 2022 in Bindura district. The change is linked to human activities that alter the natural distribution of land cover.

Figure 4:4 Bare ground Land Cover

The fig shows a general increase in bare ground in relation to the total area of the district. This means that there was an increase in human activities that depletes other land covers such as agriculture and vegetation land covers whilst extending bare ground land cover. This increase in bare ground land cover was quantified in terms of hectares and percentages as shown by the table below.

Bare Ground			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	30720.56 Ha	(13.70%)	(00.00)
2012	23441.01 Ha	(12.20%)	(-1.5)
2022	31836.4 Ha	(14.97%)	(2.77)

Table 4.4 Bare Ground Land Cover

The table 4.4 shows that bare ground continuously increased from 2002 to 2010. There was a slight increase in the bare ground land cover from the 2002 to 2010. This was attributed to better yields from crop cultivation which resulted in limited deforestation activities. I addition to this, there was limited urban expansion during that era. However, bare ground land cover increased greatly from 2012 to 2018. This was a result of increase in population growth, increase in uncontrolled forest fires and selling of fire wood by communities as a livelihood strategy in response to climate change perturbations. These results are similar to researches that were done by Muronda (2008), Kamushoko et al, (2019) Olewale et al (2003) as they identified rapid population and urban growth as key driver of increase in bare ground land cover change. It is important to note that, the research has successfully managed to fill the research gap by quantifying the extent of land cover change. More importantly, the results of this research inform the possible impacts that can come with increase in bare land cover. These effects include exacerbation of climate change impacts, increase in river siltation, environmental degradation, flooding and eutrophication of water bodies. These effects create new disaster risk in the district whilst increasing people's vulnerability to natural and man-made disasters. Therefore, there is need to up-scale measures to ensure decrease in bare ground land cover so as to ensure people's capacity, while reducing their vulnerability to disasters.

4.4.3 Built Up Area Land Cover

The fig below shows trends on build area land cover change from 2002 to 2022.

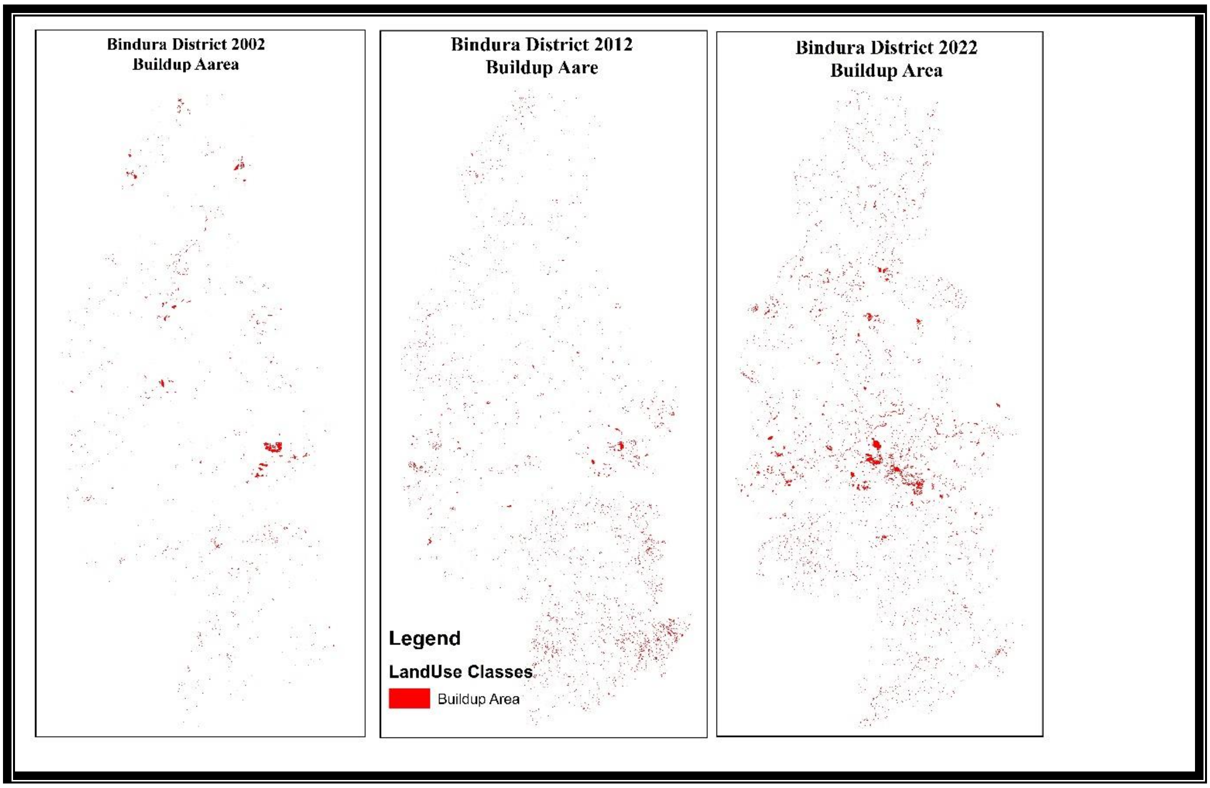

Figure 1Figure 4:5 Build-up Area Land Use

The fig 4.5 shows that there was a constant increase in built area land cover. This shows that there is a relationship between population growth and increase in built areas land cover. In addition, from the fig above it can be seen that there are large areas of build areas in certain economic zones like growth points and urban areas. This highlights that, rapid urbanization and industrialization are the major drivers of increase in land cover. The figure below quantified the increase in built area land cover in terms of hectares and percentages.

Buildup Area			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	**16142.4 Ha**	**(7.91%)**	(00.00)
2012	**20327.54 Ha**	**(9.07%)**	+1.16
2022	**24889.11 Ha**	**(11.1%)**	+2.03

Table 1Table 4.5 Build Area Land Cover

The Build-up Area has progressively increased over the years, indicative of urban expansion and infrastructure development driven by population growth and economic development. This is in line with researches that have been done at regional and national level by scholars like

Muvhura et al, (2017), Dutta, (2023), Murwira, (2011) and Chigumira at el (2019) who all points to development and urban growth as drivers of expansion of built-up areas. However, this research is important as it was able to show the change through using maps which can be used to identify the extent to which built areas are encroaching fragile environments like wetlands in the District. This is very important in coming up with risk informed development strategies, thus mainstreaming disaster management into development process. This contributes to sustainable development, which is very important in enhancing the welfare, security as well as the sustainability of rural and urban livelihoods. This will contribute to the attainment of the sustainable development goals. Therefore, there is need to use the results of this research in risk and vulnerability assessment so as to reduce disaster risk.

4.4.4 Cultivation and Farming Fields Land Use

Changes in cultivation and farming field areas from 2002 to 2022 are shown by the fig bellow.

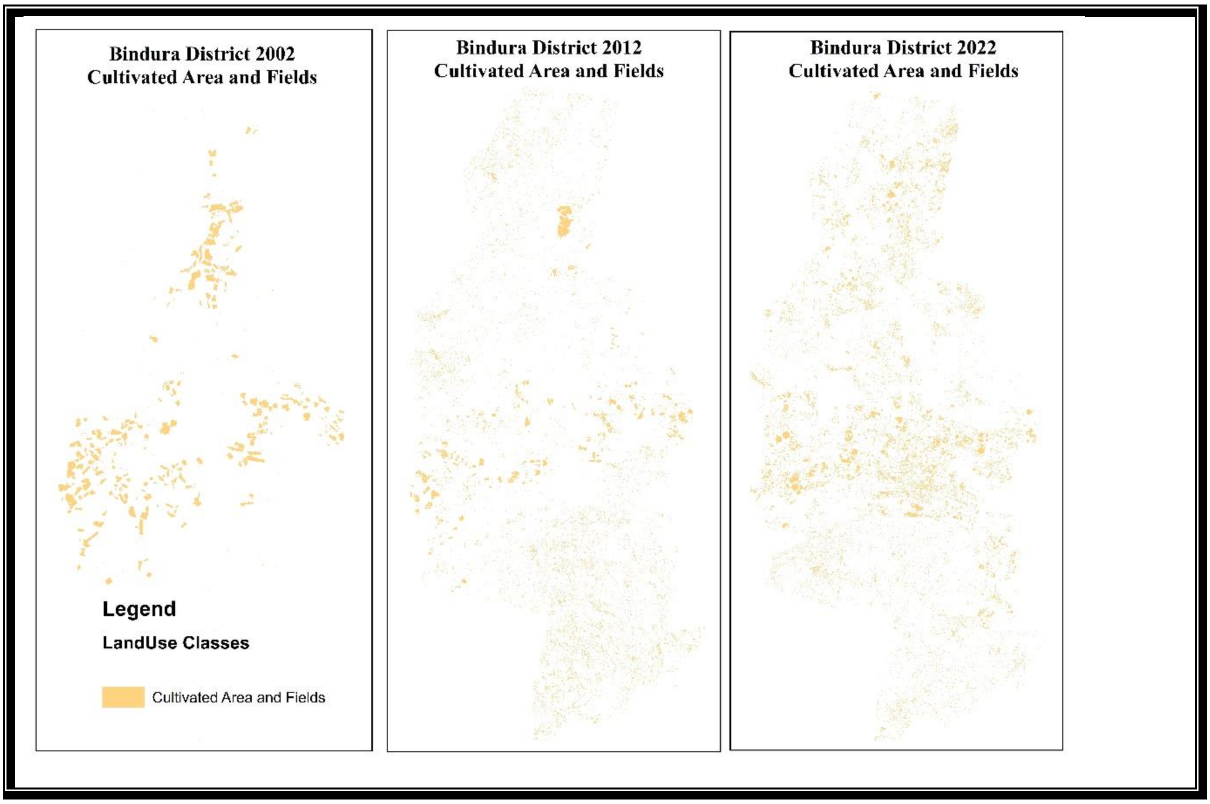

Figure 4;5 Cultivation and Farming Fields Land Use

The fig shows that there was great decrease in cultivation and farming field areas from 2002 to 2012. This was attributed to the effects of land reform form program which saw the newly resettled farmers lacking skills, farming equipment as well as lack of inputs. The period from 2012 to 2022 shows a slight increase in cultivated and farming field areas. This trend shows that resettled black farmers are struggling to increase crop cultivation because of the aforementioned challenges. This implies that, the district is at increased risk of food insecurity. Therefore, vigorous measures need to be implemented to ensure households are food insecure to prevent negative coping strategies that push people to be more vulnerable to disaster increasing disaster risk. The table below shows the decrease in hectares of areas under cultivation.

Cultivation			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	**49099.8 Ha**	**(21.84 %)**	(00.00)
2012	**36957.58 Ha**	**(16.48 %)**	-5.36
2022	**37489.15 Ha**	**(16.72 %)**	0.24

Fig 4.6 Cultivation and Farming fields Areas

There was a notable decrease in cultivated areas from 2002 to 2012, which then stabilized slightly by 2022. This change might reflect shifts in agricultural practices, land abandonment, or conversion to other land uses. This implicates food security of the District and the Nation at large. Thus this research was successful in identifying the key driver of food insecurity in the country which is decrease in land use change that undermined agricultural production.

4.4.5 Forest and Vegetation Land Cover

The fig bellow shows spatial and temporal forest and vegetation land use cover change from 2002 to 2022.

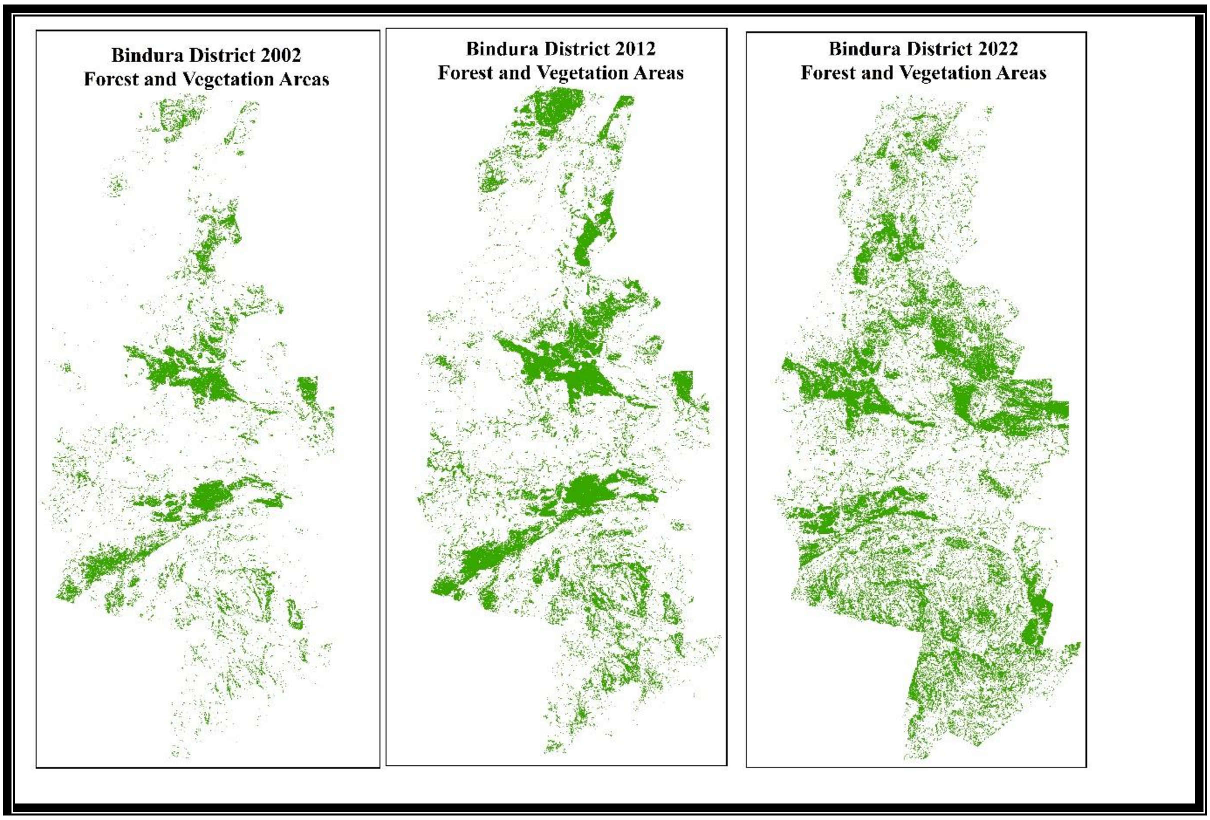

Figure 4:7 Forest and Vegetation Cover

The figure shows a general increase in forest and vegetation cover from 2002 to 2022. The same changes were quantified regarding hectares and the percentage of pixels covered by forest and vegetation land use cover. This is shown in the table below:

Vegetation			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	**41477 Ha**	**(19.15%)**	(00.00)
2012	**49539.68 Ha**	**(22.10%)**	2.95
2022	**53160.73 Ha**	**(23.71%)**	1.61

Table 4.7 Forest and Vegetation Land Cover

The figures in table 4.7 show that there was a continuous increase in the hectares covered by vegetation. This is different from researches done before by scholars like Jensen et al, (2017), and Biswas (2018), who note that there is a decrease in forest and vegetation land cover with time. However, the increase in forest and vegetation land cover in the area is attributed to mining activities. This activity dominates in the area which is causing little impact on vegetation. This is coupled by afforestation and re-afforestation programs that are causing an increase in forest and land cover area. These highlights better forests and vegetation management over the years.

4.4.6 Rock and Mountain Land Cover

The images below show changes in rock and mountain land cover over the years.

Figure 4:8 Rock and Mountain Land Cover

Fig 4.8 shows a general decline rock and mountain area over the years. The decline is attributed to mining activities on mountain as well as vegetation regeneration that is covering some bare rocks. In addition to this construction of houses on mountain in the district is also contributing to a decrease in mountain areas.

Mountain Area			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	**24549.9 Ha**	**(11.67 %)**	(00.00)
2012	**19089.69 Ha**	**(8.51 %)**	(-3.16)
2022	**15315.77 Ha**	**(6.83 %)**	(-1.68)

Table 4.8 Mountain Area

The Mountain Area shows a consistent decline over the years, indicating possible deforestation or land conversion for agriculture or urban development and mining

4.4.7 Water Area Land Cover

Images below shows water areas land cover.

Figure 4:9 Water land cover

Fig 4.9 shows a no change in terms of the water areas land cover. However, quantification of the pixels covered by water showed that there is a slight decrease in water areas land cover. This is illustrated by the table below.

Water			
Years	**Ha**	**Percentage Cover**	**Percentage Change**
2002	**7174.4 Ha**	**(3.71%)**	**(00.00)**
2012	**5399.95 Ha**	**(2.41%)**	-1.3
2022	**7177.31 Ha**	**(3.20%)**	0.79

Table 4.9 Water Areas land Cover

Water bodies experienced a significant reduction from 2002 to 2012, followed by a slight increase by 2022. The decrease in water area might be attributed to factors such as climate change, water extraction, or land reclamation activities.

4.5 Critical trends in Bindura District's LULC changes

They are a sign of urban expansion which saw a steady increase in built-up area which underscores on-going urbanization and infrastructure development, likely driven by demographic and economic pressures. The District is also characterised by agricultural dynamics, thus there is fluctuations in cultivation and agriculture areas suggesting varying agricultural practices, possibly influenced by policy changes, market conditions, and environmental factors. Due to the increase in vegetation it is a sign of vegetation recovery. The consistent increase in vegetation land cover suggests successful re-afforestation initiatives, natural regrowth which is highlighting positive environmental management efforts in the area. There is also a reduction in mountain area and the fluctuating water and bare ground areas signal environmental stresses that might be linked to anthropogenic activities such as deforestation, water extraction, and land degradation, mining, urbanisation and development

4.6 Spatial and Temporal Analysis of Human Activities on Land Use Cover

Land use and land cover (LULC) changes are crucial indicators of human activities and their impact on the environment. Understanding these changes over time provide insights into the dynamics of landscape transformation due to various anthropogenic and natural factors. The dataset encompasses various land classes measured in hectares (Ha) and their corresponding area percentages over three years that is 2002, 2012, and 2022. The land classes include Water, Mountain Area, Cultivation, Bare Ground, Vegetation, Agriculture Area, and Build-up Area. The total land area remains constant at 224,200 hectares across all years, facilitating a straightforward comparative analysis.

4.7 Conclusion

The chapter presented the findings of the study concerning the research objectives. It first analysed land use cover change in Bindura District. The analysis shows that there was a change in land use cover over time. The research also presented the findings on homogenous land use and land cover (LULC) types. The finding shows that there was a constant increase in vegetation, built area and bare ground land cover. The analysis of results shows that these changes increase the vulnerability of people to hazards such as droughts, disease outbreaks and flush floods. The impacts of human activities on LULC in the study area were also identified and these include rapid urbanization, development, mining and abandonment of crop farming.

CHAPTER 5

CONCLUSIONS AND RECOMMENTATIONS

5.1 Introduction

This Chapter presents conclusions and recommendations based on the results obtained and their analysis in relation to spatial-temporal Land Use Change in Bindura District.

5.2 Conclusions

Physical, socioeconomic, and institutional reasons are the main causes of the shift in land cover in the Bindura district. Both in terms of percentage (%) and spatial area (m2), the size and rate of change in land cover, whether it be an increase or reduction, have always exceeded zero. The transformation of agricultural land and forests into bare earth, developed areas, and vegetation has been the most prevalent type of change. The Bindura District as a whole is affected by the change in land cover; it is not limited to any one area. Major steps toward closing the information gap and building a database for tracking changes in land use and land cover are represented by the change estimates and patterns of change outcomes. This endeavor would serve as a foundation for subsequent research projects and aid in the decision-making process regarding the mitigation of the effects of changing land cover on these resources.

5.3 Recommendations

The following recommendations should be adopted for natural resource management and policy formulation for better decision making to curb the negative spatial-temporal changes that can threaten people's livelihoods and increase the vulnerability of people to disasters as well as to enhance sustainable management of natural resources.

- There is need to curb negative land use change like increase in bare ground, through awareness programs that educate people on the sustainable ways of managing vegetation cover and the benefits that come with it. That is regulation and provisioning services obtained from sustainable ecosystem management.
- The continual increase of illegal gold panning and occupation by people in the farming areas need to be checked by promulgating a law of unlawful entry hence this would protect the natural resources in the study area
- Adequate continuous monitoring by making use of satellites and remote sensing should be encouraged
- The people in the study area should be enlightened or educated on how to manage and protect the environment

- The area should not be turned into common property as this would affect effective land use planning
- Wildfires issues need to be addressed holistically with a collective approach with the community so as to reduce and try to stop those fires
- In addition, more research needs to be done on the farms, especially on the effects of land fragmentation

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SPATIAL-TEMPORAL ANALYSIS OF LAND USE / LAND COVER CHANGES IN BINDURA DISTRICT USING GIS AND REMOTE SENSING.

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