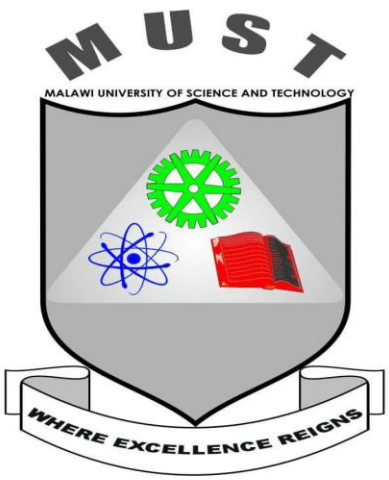


ASSESSING THE NEGATIVE IMPACTS OF BUILDING CONSTRUCTION ACTIVITIES ON VEGETATION IN ZOMBA CITY, SOUTHERN REGION, MALAWI

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Thyolo, Malawi

Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfillment of the requirements for the award of Bachelor of Science degree in Geo Information and Earth Observation Sciences

JULY, 2021

DECLARATION

I Alex Kasakula declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for academic purpose. All sources of information have been appropriately acknowledged.

Signature 

Date July 20,2021

DISSERTATION APPROVAL

SUPERVISOR: Mr. D Mbeya

Signature: _____

ASSESSOR:_____

Signature: _____

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ABSTRACT

The building construction industry is well known as a source of negative environmental impacts, which are associated with production and extraction of raw materials. Some of the major impacts caused by the industry are deforestation, degradation of urban landscape, ecosystem destruction, resource depletion, land pollution, air pollution, natural disaster, effect on biodiversity and noise pollution amongst others. Therefore, the study is mainly focusing on identifying the major negative impacts of various building construction activities on vegetation. However, ways of minimizing the negative impacts of building construction activities on vegetation should be applied and followed. The collected data was analyzed using ArcGIS, Qgis, and ENV softwares to interpret and further analyze the Landsat satellite images. Supervised Image classification analysis was also employed to generate Landcover maps, NDVI, and NDBI maps. However general guidelines on the selection for the most appropriate methodology in relation to the research aims and objectives may also be proposed.

ACKNOWLEDGEMENT

I acknowledge the almighty Lord for the love and care throughout the entire period of this research project. Many people have assisted me in one way or another, and it would be hard to mention each one of them. To all I extend my appreciation, however it is worthwhile to mention a few individuals who have contributed much to my project from the early stage of title formulation, implementation up to write up. To my supervisor, Mr. D Mbeya, I greatly appreciate your encouragement, technical assistance and advice throughout the research period. I express my special gratitude to all my family members for all the financial support and encouragement

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ACRONYMS/ABBREVIATIONS

ETM+	Enhanced Thematic Mapper Plus
ENVI	Environment for Visualizing Images
MASDAP	Malawi Spatial Data Portal
NDBI	Normalized Difference Built up Index
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared
NSO	National Statistics Office
OLI	Operational Land Imager
SCP	Sem-Automatic Classification Plugin
SQKMS	Square Kilometers
SWIR	Short-Wave Infrared
TIR	Thermal Infrared Sensor
TM	Thematic Mapper
USGs	United States Geological Surveys

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CHAPTER ONE

1.0 INTRODUCTION

Environmental degradation as a result of building construction activities is one of the recently most discussed subjects locally, nationally and globally (Bentivegna, 2012). Many people manipulate the natural environment in order to improve the living standards by creating amnesties such as buildings, bridges, highways and others. The building construction industry is well known for negatively affecting vegetation by disturbing its coverage and chopping of trees to clear the ground, and its impacts have increased with development process of cities. As a result, the execution of a construction project is subject to numerous constraints that limit the environmental or progression of field operations, which invariably have significant negative impact overall project performance (Michael Pacione, 2009). Although there are several studies focused on the environmental impact of residential and commercial buildings, less has been done to decrease the building construction impacts especially in urban projects.

In the last decade the population of Zomba city has been increased substantially, as people seek a higher quality of life, which includes scenic beauty, access to public land (for buildings) and opportunities for outdoor recreation (Malawi Population Housing and Census, NSO: 2018).

Successful execution and control of building construction activities relies on effective identification, utilization and management of constraints through master planning and short-term scheduling.

1.1 PROBLEM STATEMENT

Building construction activities is one of the sources of negative environmental impacts, these may be associated with production and extraction of raw materials. Some of the major negative impacts caused by the industry on vegetation are deforestation, effects on vegetation important role in hydrologic cycle and catchment erosion, disturbances in vegetation coverage amongst others. According to a research published in UN-

HABITAT's flagship report (2011), Zomba lacks a city development strategy on Urban Master Plan and Development Plan to ensure guided development. This has put the building construction industry under investigation since its activities significantly influence the vegetation and its constituents.

1.2 RESEARCH QUESTIONS

- What are the major negative impacts of building construction activities on vegetation?
- What are the best practices to be followed in building construction activities?

1.3 RESEARCH OBJECTIVES

1.3.1 Main objective

- To identify the major negative impacts of building construction activities on vegetation

1.3.2 Specific objectives

- To identify the extent in terms of percentage and area coverage to which building construction activities are negatively impacting vegetation
- To predict ways of minimizing the negative impacts of building construction activities on vegetation.

1.4 JUSTIFICATION OF THE STUDY

The building construction industry plays a significant role in the provision of physical infrastructure to meet the needs of the society. Therefore, the development of building construction activities with less environmental impacts is a major improvement opportunity, especially regarding decision-making at the design stage, which gives bound to allow the control of negative impacts at its source. The area was chosen because its current environment and climatic condition due to some of building construction activities is worth an investigation. Building construction activities are some of the developments which are dominating, hence greatly impacting the environment negatively particularly the vegetation. Hence, this study is so useful for documentation and to fill the gap on building construction activities on vegetation in Zomba city

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 THE CONSTITUTION OF THE REPUBLIC OF MALAWI

The state affairs of the building construction industry in **Zomba city** are not different from other cities in Malawi and other developing countries in Africa. The focus of building construction activities is mainly based on economic growth and improving the quality of life of the people whilst environmental protection is utterly downgraded. Zomba city, like many other parts of Malawi is experiencing widespread challenges in environmental issues which have risen as a result of improper utilization and management of environment in general (Zomba District Socio-Economic Profile, 2017-2022). The government of Malawi has provided insights on how the country can address these perceived construction and development issues on land and environment. The constitution of the republic of Malawi (1995) sets broad framework for sustainable environment management at various levels in Malawi. A sustainable development vision is ensured with the call for prudent management of the environment and accordingly to future generations' rights to environment.

The constitution also provides for a framework for the integration or application of international environmental and foreign case law into the rational legal system.

2.2 PRODUCTION OF BUILDING CONSTRUCTION MATERIALS

Production of building construction materials is one of the major sources of air pollution. Cement production, asphalt concrete and glass have considerable contribution of air pollution. The production process also consumes considerable amounts of energy. For example, the cement industry pollutes on four fronts (The Indian Cement Industry, 2005). Effluent discharges from the industry invariably find their way to the nearby rivers or streams and consequently raise ph value of stream water; there are spillages of cement slurry and raw meal.

Cement industries emit carbon monoxide, sulfur and nitrogen oxide, there are also stack emissions of kiln flue dust in the form of smoke and particulates, the production of 1 ton of cement involves 2.6 to 2.8 tons of raw materials (Future foundations, 2002).

The vivid description of how Nigeria building construction destroys the environment indicates that every tree loses its life. Ancient buried river valleys or nearby gullies as well as a stream channels are just shoddily covered with silt, dry mud or red earth, no solid or wide gutters or solid road stabilization is part in place (Egboka, 2000).

2.3 INTERNATIONAL JOURNAL OF RISK AND CONTINGUITY MANAGEMENT

Most researches have used the fuzzy expert as a tool for analyzing building construction risks (Fouladgar, Yazdan-Chamzini, & Zavadskas, 2012). Another research method used for risk analysis is the use of questionnaires, literature reviews, interview and experts' opinion to identify risks and the quantification of data's to be interpreted using statistical means (Ameyaw & Chan, 2015; Chileshe & John Kikwasi, 2014). Multi-criteria decision method to validate random block squares as a tool for evaluating risk in construction projects can be used (Xu, 2012)

There are developed framework that lies on the newly introduced fuzzy-set based model for estimating, allocating, depleting and managing contingency fund over the lifecycle of construction projects (Salah & Moselhi, 2015)

However, the problem related to building construction projects were addressed, it falls to strengthen the reliability and validity of the measurements.

2.4 PREVIOUS INTERNATIONAL BUILDING CONSTRUCTION RESEARCHES AND ENVIRONMENTAL MANAGEMENT ACTIVITIES

There are different causes of negative impacts in building construction activities such as size, organizational and technical complexities, speed of construction, location of the project, technology being used and familiarity with work (Dey & Ogunlen, 2004). In addition to this, projects managers have to consider a growing number of parameters (e.g., environmental, social, safety and security) and stakeholders, both inside and outside the project. The complexity of a project leads to the existence of a network of

interdependent impacts Fang & Marle, 2012) where phenomenon may occur, hard to anticipate and hard to keep under control (Fang & Marle, 2013).

Impacts, risks and uncertainties are inherent in all construction activities no matter what the size of the project is (Carr & Tah, 2001, Jha & Devaya, 2008). These impacts, risks and uncertainties are measures of the probability, severity and exposure to all hazards of an activity (Sarkar & Panchal, 2015). Risk is closely commonly used term in all kinds of context, but is often related to the negative outcome of a certain event, moreover risks have stochastic nature (Hamzaoui, Taillandiei, Mehdizadeh, Breysse, & Allal, 2015).

Unexpected impacts involve the threat of uncontrollable, unpredictable and unanticipated events, which are especially considered by the management of large-scale projects, since these are unexpected risk events (Hamzaoui at al, 2015, Huang, Huang & Hsieh, 2013). These impacts have a direct influence on projects success. Many construction projects tend to exhibit cost overruns and schedule delays (Koushki, Al-Rashid, & Kartam, 2005; Mahammad, 2011; Sarka, 2012). Many researches conducted in different parts of the world revealed that impacts have resulted in significant cost and time overrun of the projects (Floricel & Miller, 2001).

The literature on impacts and its assessment in construction projects is vast because project impact factor research has been (and continue to be) of interest to both academics and practitioners (MEZHER & TAWIL, 2002). The area of impact management has received recognition in the field of project management in recent years while the financial and economic crisis is evident globally. It is very important to understand the actual practice of impact analysis and review the development of construction impact and risk modelling and assessment in an attempt to research viable alternatives that may contribute to closing the gap. However, few researches are there to summarize and capture the essential contribution and gaps of the previous researches.

This review is confirming what was previously mentioned, that the literature lacks a comprehensive risk assessment framework which take into account the types of impact of the risk on different construction projects simultaneously.

CHAPTER 3

3.0 METHODOLOGY

3.1 Study area

The study took place in **Zomba district** particularly ***Zomba city.*** This section shall explain the nature of data collected, data sources and analysis and limitations of the study.

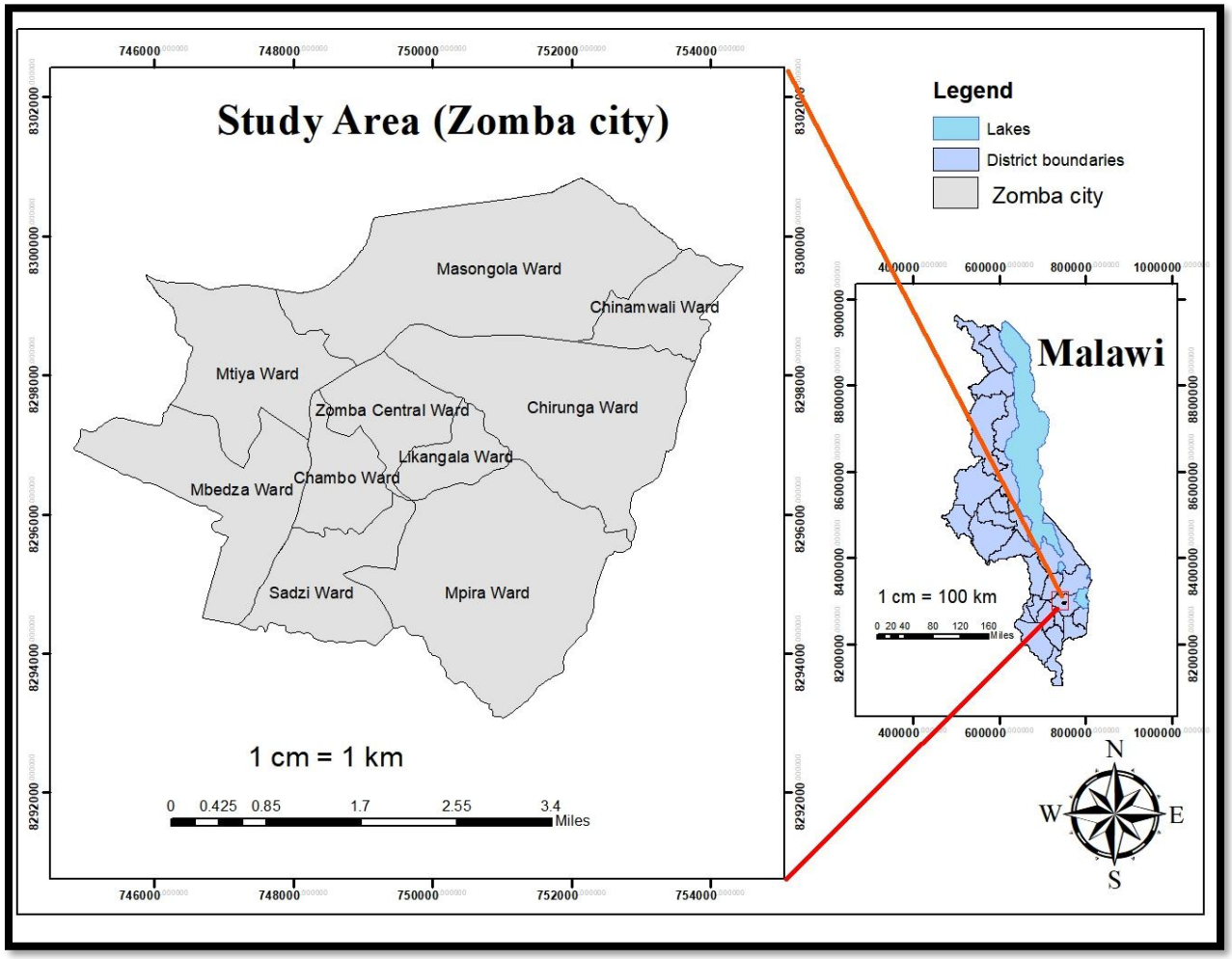


Figure 1: Geographic location of the study area.

3.1.1 Location and size of the study area

Zomba city is located at the Centre of Zomba District in the Southern Region of the Republic of Malawi, Southern Africa. It covers an area of 39 square kilometers and shares all its boundaries with Zomba District Council, which forms an integral part of its sphere of influence. Zomba city is the fourth largest urban Centre in Malawi after Blantyre, Lilongwe and Mzuzu. It is situated along M3 Road about 65km north of Blantyre (main commercial Centre) and about 300km South east of Lilongwe (the capital city)

Zomba city is located at the foot of Zomba plateau. Zomba plateau is 2085m above sea level. It is the fourth highest plateau in the country after Mulanje, Nyika, and Vipya. The plateau is one of the renowned tourist attractions in the country because of its diverse natural resources and scenic beauty. (Zomba City Council, 2020).

3.1.2 Climate

Zomba experiences tropical climate, which has three seasons namely: hot rainy, cool dry and hot dry seasons. The hot rainy season starts from November and ends in April. Cool dry season occurs from May to July while hot dry season occurs from July to October

3.1.2.1 Temperature

The average monthly temperature for Zomba is 21.1°Celcius with minimum of 11.5°Celcius in June and mean maximum of 20. 8°Celcius in October

3.1.2.2 Rainfall

Zomba receive annual rainfall between 600mm to 1500mm. Normally high rainfall occur in January and February hence the wettest months in a year.

3.1.3 Topography and Geology

The topography varies between undulating to flat. The topographical characteristics cause climatic diversity. Metamorphic rocks of sedimentary and ingenious underline the district. These are different types of minerals and these include limestone currently being mined commercially in the district.

3.1.4 Environment and Vegetation

The environmental situation in Zomba city is fast det deterioting due to fast loss of forest cover. Deforestation is occurring at a fast pace as a result of human encroachment in protected forests for purposes of agriculture expansion, increasing demand for fuelwood, and higher timber requirements. The rate of forest destruction is further aggravated by infrastructure development such as the construction of Mulunguzi Dam and expansion of district road network.

3.2 RESEARCH DESIGN

3.2.1 Sources of data

The analysis of this study was based on the secondary data. The sources of the data comprise those data obtained from the internet sources. In this study the data used were Landsat images, Google Earth Satellite images, OpenStreetMap, Journals, Articles and different shapefiles collected from Malawi Spatial Data Portal (MASDAP)were used.

3.2.2 Conceptual framework

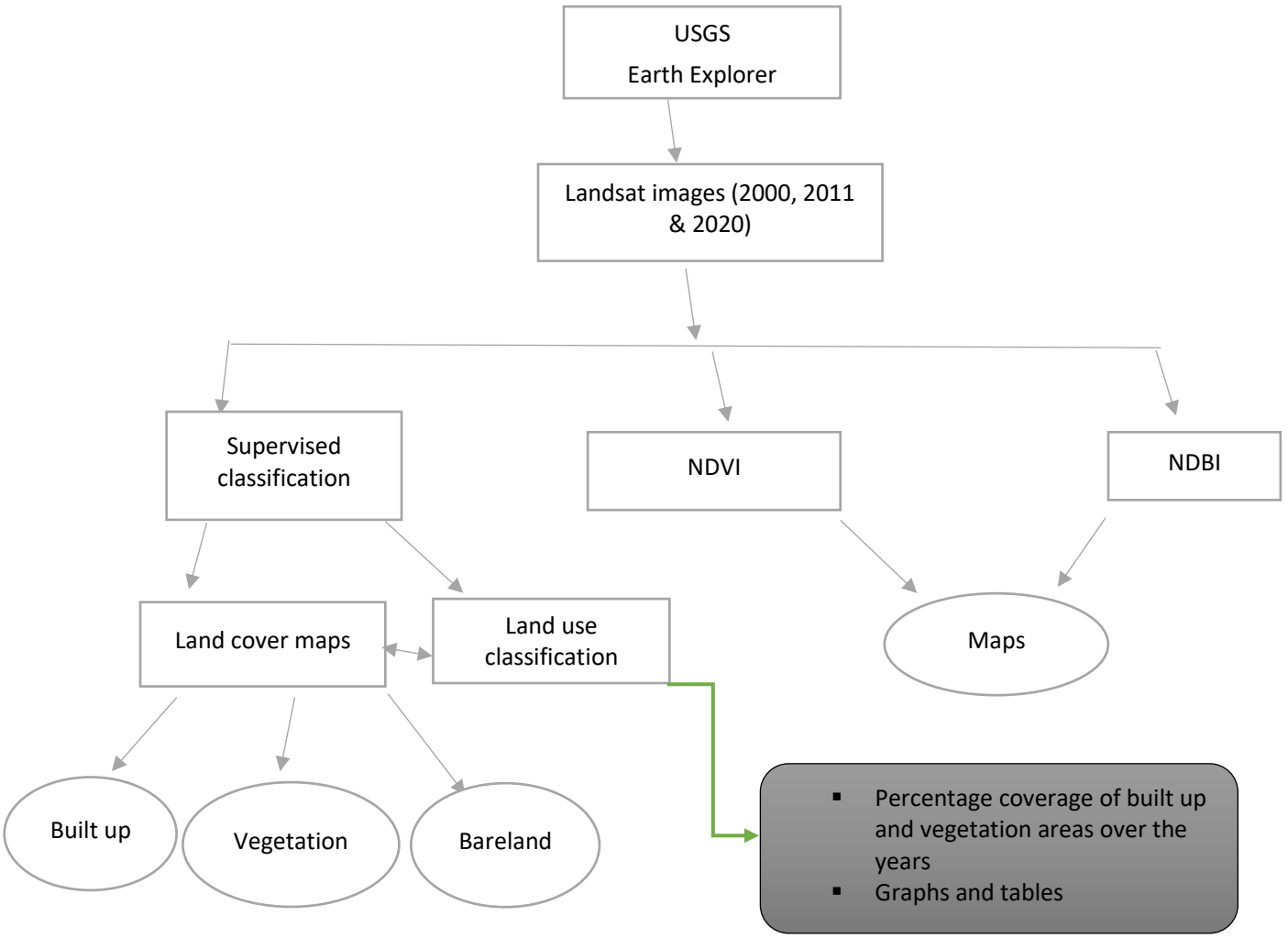


Figure 2: The steps of the analysis that shall take place in this study.

Materials and Methods

3.2.3 Data selection and collection

Landsat images from the years 2000,2011 and 2020 were downloaded from the United States Geological Surveys (USGs), Earth Explorer. These three satellite images were selected in relevance to the purpose of this study, thus the objects, months of acquisition and

availability. Based on literature and previous studies, Landsat imagery data is one of the most used satellite images in change detection projects over the years.

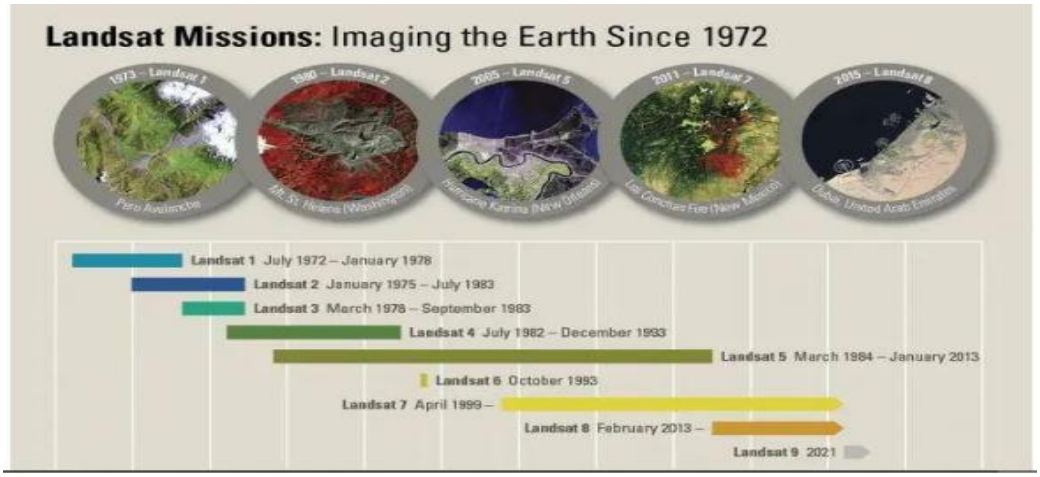


Figure 3*: The journey of Landsat program (Courtesy of Earth Explorer, USGs).*

Landsat 5 TM: Landsat 5 TM was launched on March 1, 1984 and deactivated on June 5, 2013. Despite a three-year design life, Landsat 5 operated for nearly 29 years. Because of its durability, it is recognized in the Guinness World record for the longest operating Earth Observation Satellite in history. Landsat 5, is a collected imagery for major purpose/events including change detection, monitoring pollution, devastating tsunamis and deforestation. It had the Thematic Mapper hence Landsat 5 image are consistent with its immediate predecessor. Landsat 5 TM was decommissioned in 2013.

Landsat 8 OLI: This satellite has two combining for 11 total spectral bands. Seven of the eleven bands are basically consistent with ETM+ found on Landsat 7. Landsat 8 bands include coastal, blue, green, NIR, SWIR, SWIR 2 and cirrus bands at 30m resolution while the panchromatic has 15m resolution. TIRS is 100m pixel size.

- Landsat 5 TM 2000: this is representing early stage before major building construction activities in Zomba city
- Landsat 5 TM 2011: this is indicating the status of the beginning of major building construction activities in Zomba city

- ❖ Landsat 8 OLI 2020: representing the current status within Zomba city and surrounding areas

These images were downloaded between September and October because this is the period that represents dry season in Malawi.

Table 1: Description of Satellite Imageries used in this study.

Year	Day	Satellite Imagery	Spectral Resolution	Spatial Resolution	Bands
2000	01 September	Landsat 4/5 TM	7	30m,120m	Blue, Green, Red, NIR1,NIR2,MIR,Thermal
2011	18 October	Landsat 4/5 TM	7	30m,120m	Blue, Green, Red, NIR1,NIR2,MIR,Thermal
2020	10 October	Landsat 8 OLI	11	15m,30m,100m	Coastal, Blue, Green, Red, NIR, SWIR, SWIR 2 and Cirrus bands

3.2.4 Image pre-processing and analysis

The process of image pre-processing and analysis is too complex. It can be done in two methods namely: analogy (visual image interpretation) or digital image analysis(computerized). In this study the image pre-processing was done digitally using Qgis 3.18 software. All map generation were done using Qgis and ArcMap 10.5 as well as the ENVI 5.3 software for outputs from the classification analysis.

3.2.5 Image pre-processing

Several image pre-processing steps were followed after the satellite images were obtained. The pre-processing included projection of the Landsat bands in relevance to ARC1950/WGS1984 which is used in Malawi. The satellite imageries were reprojected using Qgis 3.18 software (Zurich version). Atmospheric and radiometric correction were performed using the Sem Automatic Classification Plugin (SCP) version 7.0 which was installed in Qgis. All these steps were done to prepare the satellite imageries for different analysis namely: Land use classification, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built up Index (NDBI).

3.2.6 Supervised Image Classification

The Supervised Classification technique is a user-guided type of classification which requires the analyst to have a prior knowledge of the spatial and spectral characteristics of the land cover classes. In this study, supervised classification was done using the Environment for Visualizing Images (ENVI) version 5.3. Over a thousand of pixels were obtained for each and every class of interest. The training classes were Vegetation, Built up, and Bare land. The training classes were performed for all the Landsat satellite images downloaded using the Maximum likelihood supervised classification. The majority post image classification was done for all the images to further smoother the images for easy and interpretation of information required for the study. All these steps were followed to prepare the images for further analysis. In this study the further analysis was NDVI to map out green areas of Zomba city, NDBI to generate built up areas in Zomba city, and Land use classification for generation of land cover maps. Charts, tables and graphs were also generated after the Supervised classification. The final outputs of the classification were performed using ArcGIS and Qgis softwares.

CHAPTER 4

4.0 RESULTS AND DISCUSSIONS

4.1 Results of NDVI analysis

The NDVI of Zomba city have been calculated for the years 2000, 2011 and 2020. For Landsat 5 TM, the NDVI is calculated using band 4 and band 3 whereby band 4 represent NIR and band 3 represent the Red (visible region).

NDVI = NIR – RED/NIR + RED

The description of the results of NDVI have been given by NDVI maps, a summary and a table below:

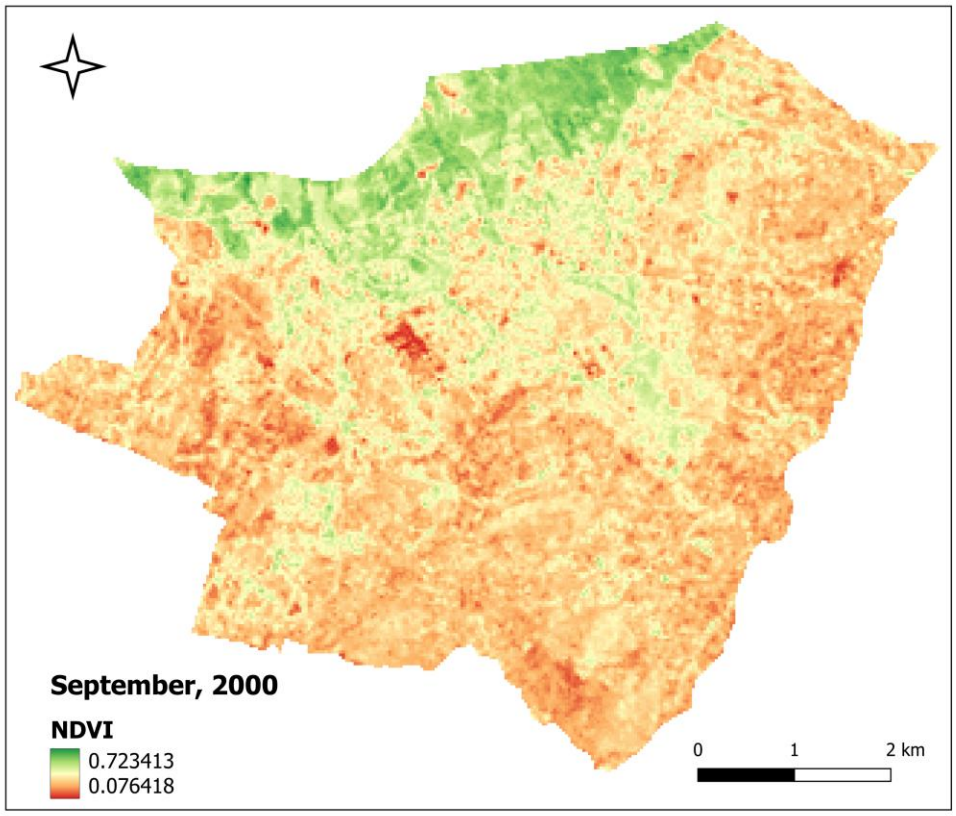


Figure 4: Map showing vegetation distribution in Zomba city, 2000.

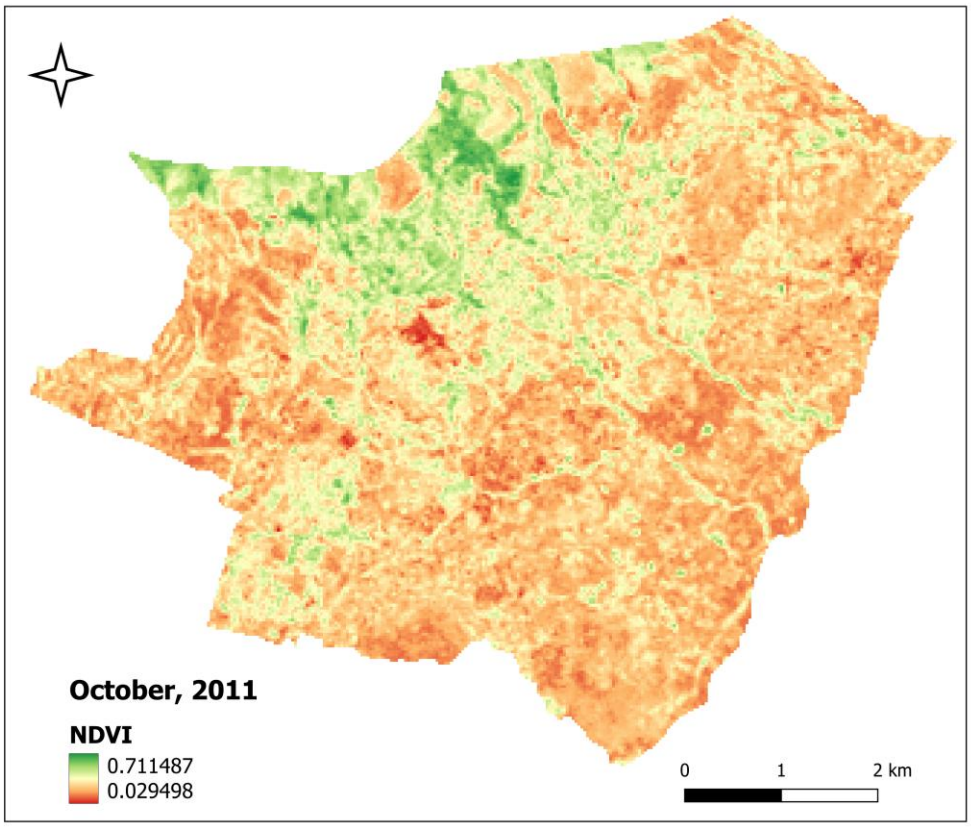


Figure 5: Map showing vegetation distribution in Zomba city,2011.

For Landsat 8 0LI/TIR satellite imagery, the NDVI is calculated using band 5 and band 4 whereby band 5 represents NIR and band 4 represents the RED band. Below are the results of NDVI for Landsat 8 OLI/TIR.

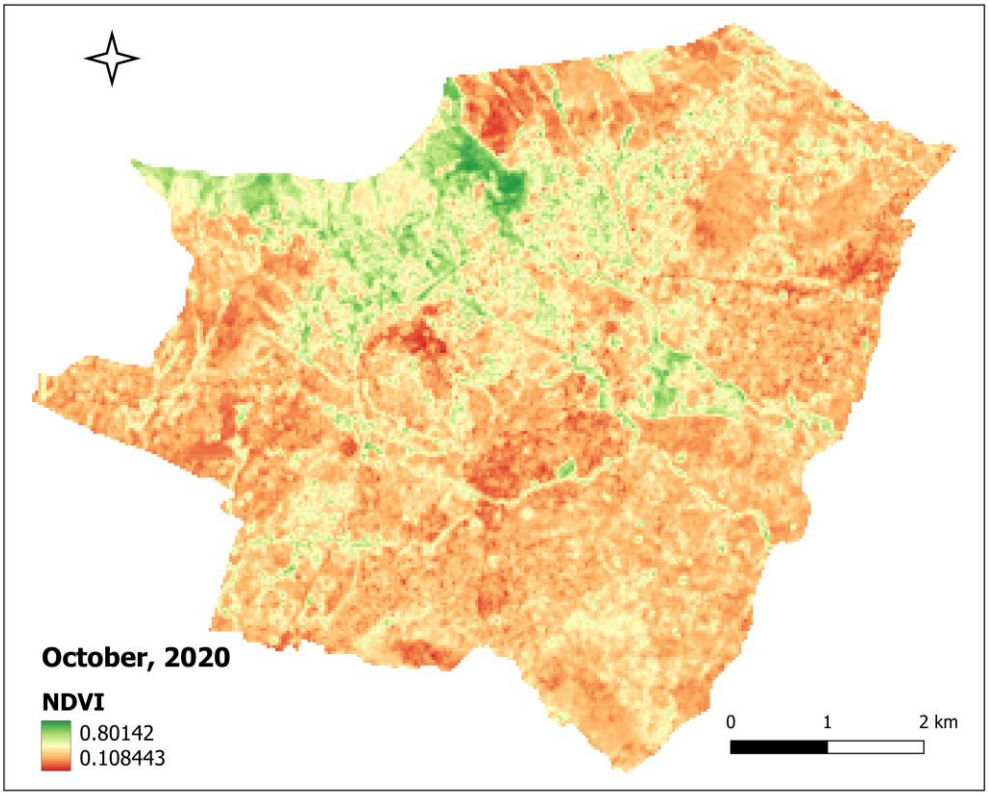


Figure 6: Map showing vegetation distribution in Zomba city,2020.

4.1.1 Summary of the NDVI results

The NDVI values helps to distinguish different parameters. Each value has a specific meaning e.g., for dense or sparse vegetation. For example, shrubs or grassland values ranges between 0.2-0.5. The NDVI for Zomba city has been dramatically changing over the years from 2000 to 2020. From 2000 to 2011 the highest NDVI value has decreased with the margin of 0.11926. From 2011 to 2020 the highest NDVI value has contrary increased by the value of 0. 078007. The increment has only been observed for a small part in the study area. From the values, it is observable that vegetation coverage around the city is decreasing. Some areas which were previously showing a high NDVI value are now showing lower values. From 2000 to 2011, the north east part of Zomba city was dominated with vegetation unlike in 2020. This means that the vegetation class has either

transitioned to other classes or decreased with a great impact due to the building construction activities as Zomba city is rapidly increasing in recent years. Below is the table indicating the highest and lowest NDVI values for Zomba city over the past 20 years.

Table 2: NDVI values for Zomba city

YEAR	SATELLITE IMAGERY	HIGHEST VALUE	LOWEST VALUE
2000	Landsat 5 TM	0.72341	0.07041
2011	Landsat 5 TM	0.711487	0.029498
2020	Landsat 8 OLI/TIR	0.80142	0.108443

4.2 Results of NDBI analysis

The NDBI was also calculated for all the years 2000,2011 and 2011. For Landsat 5 TM, NDBI is calculated using band 5 and band 4 whereby band 5 represents SWIR and band 4 represents NIR.

NDBI = SWIR – NIR/ SWIR + NIR

The NDBI maps are presented in black and white colors (panchromatic). The white color represents the built-up area whilst the black color represents least or non-built-up areas.

The following are the outputs for the NDBI for the years 2000 and 2011. In 2000, Masongola ward and Northern part of Mtiya ward had least built-up area as compared to the other wards. Meanwhile, West Mtiya, Zomba central, and Sadzi ward show high NDBI value hence more built-up area. There is an increase of built-up area in most wards of Zomba city in 2011 except Masongola ward which has lost some portions of non-built-up area especially to the Eastern part. In contrary to this, Mbedza, Chambo, Zomba central, and Mtiya ward show some slight rise in built-up area.

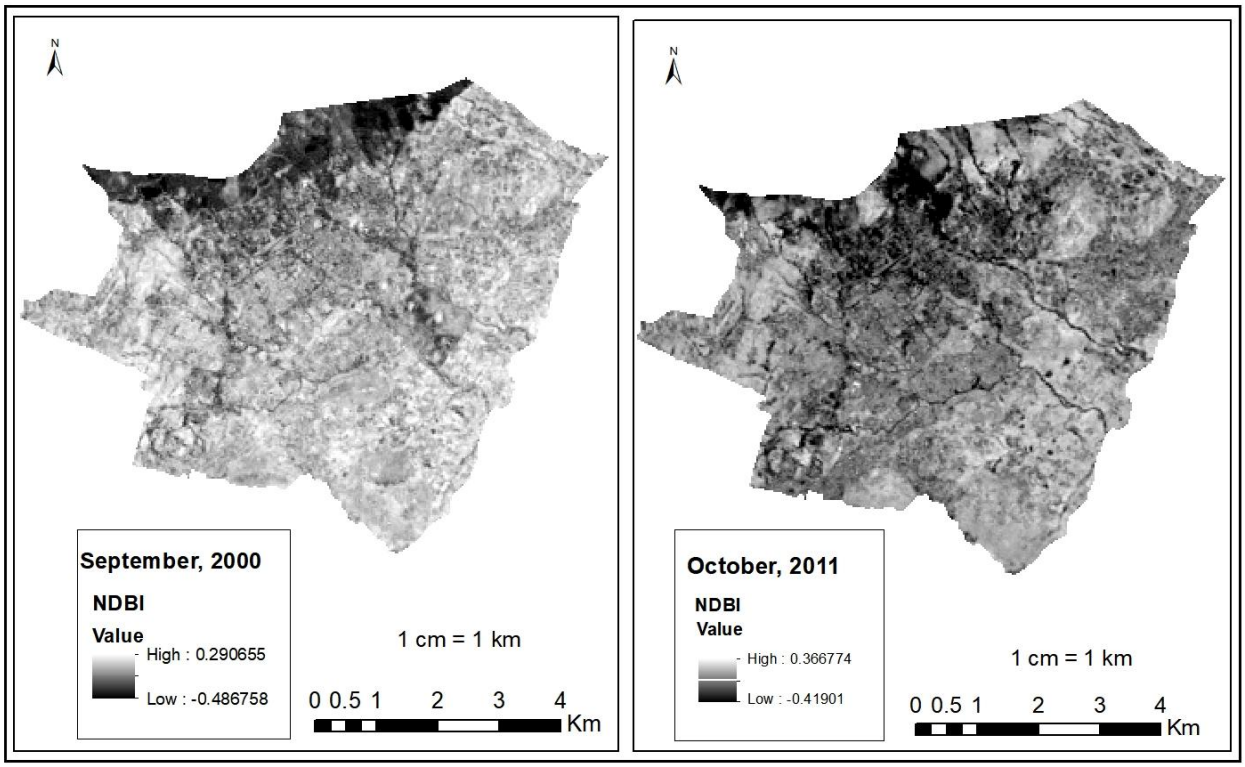


Figure 7: Map showing NDBI for Zomba city in 2000 and 2011.

For Landsat 8 0LI/TIR satellite imagery, the NDBI is calculated by band 6 and band 5 whereby band 6 represents SWIR and band 5 represents NIR. Below are the results of NDVI for Landsat 8 OLI/TIR.

In 2020, there is a great increase of built-up area in Masongola, Chilunga, Chinamwali, Mtiya, and Mbedza ward. Non-built-up area for West Masongola ward and some parts of Mtiya, Likangala, and Chilunga ward have slightly rise. This is in line with the earlier observation of 2020 Zomba NDVI map in which the highest value increased by value of 0.078007.

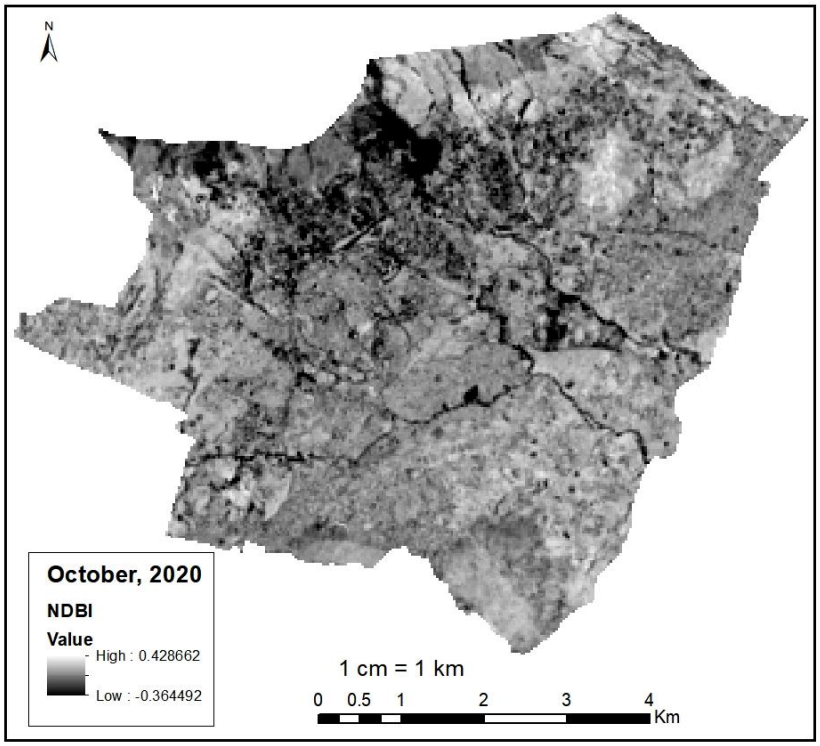


Figure 8: Map showing NDBI of Zomba, 2020

4.2.1 Summary of the NDBI results

The highest NDBI values for the built up have rapidly increased. In contrary to that, the lowest NDBI values are going down. Below is the table showing the NDBI values for the years 2000,2011, and 2020.

Table 3: NDBI values for Zomba city

YEAR	SATELLITE IMAGERY	HIGHEST VALUE	LOWEST VALUE
2000	Landsat 5 TM	0.290655	-0.486758
2011	Landsat 5 TM	0.366774	-0.41901
2020	Landsat 8 OLI/TIR	0.428662	-0.364492

4.3 Results of Classification of Landsat Images

The classification analysis of the satellite imagery data used in this study has helped in producing important Land cover maps. These were so significant in determination of the area coverage by each class for all the years. Fig (9) below is showing the summary of the classification analysis for 2000 Landsat 5 TM. Land cover map for the classes has been summarized in (Fig.10). Based on percentage, the analysis has shown that the major part of landcover area in Zomba city was bare land (43.70%) seconded by built up (29.78%) and finally vegetation (26.52%).

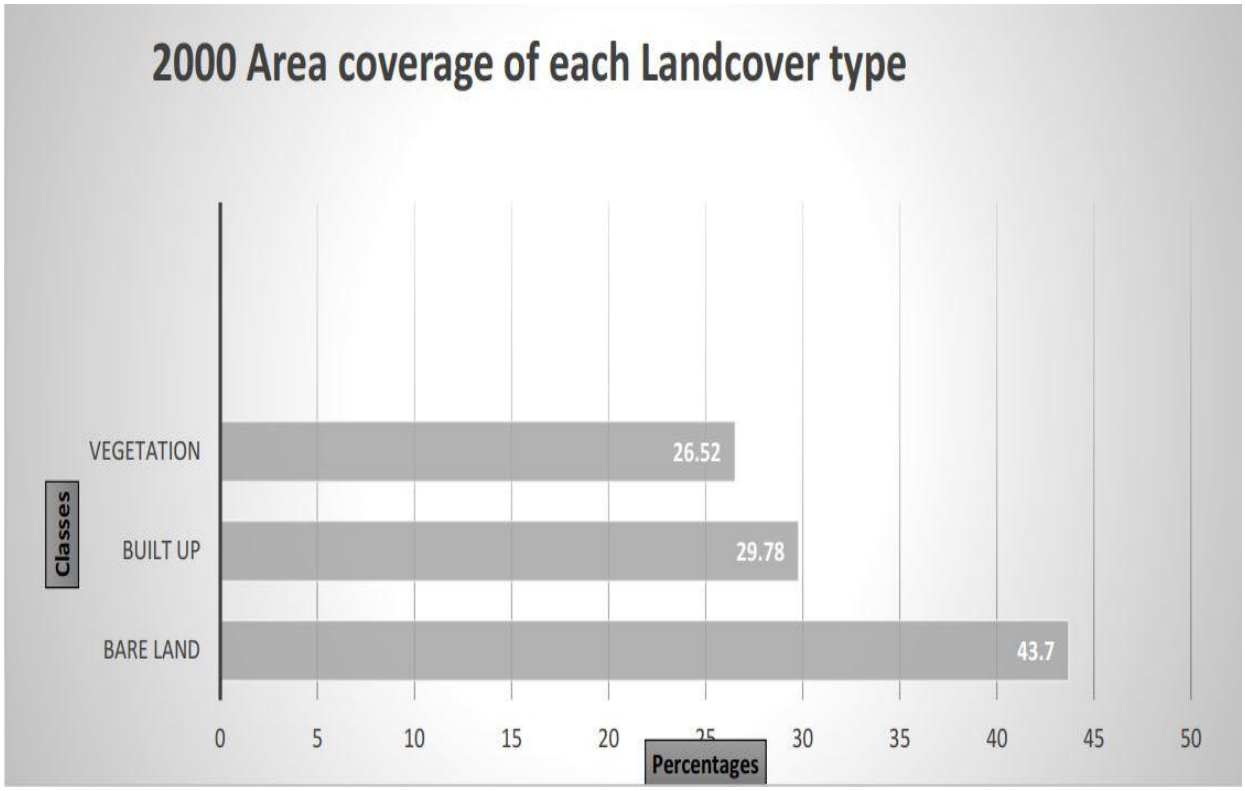


Figure 9: Area covered by each Land cover type in 2000

There is minimal difference in area and percentage coverage between vegetation and built-up in 2000. Percentage difference is 3.26 whilst that of area coverage is 1. 3579 sqkms. This marked the initial point of the study for the years chosen.

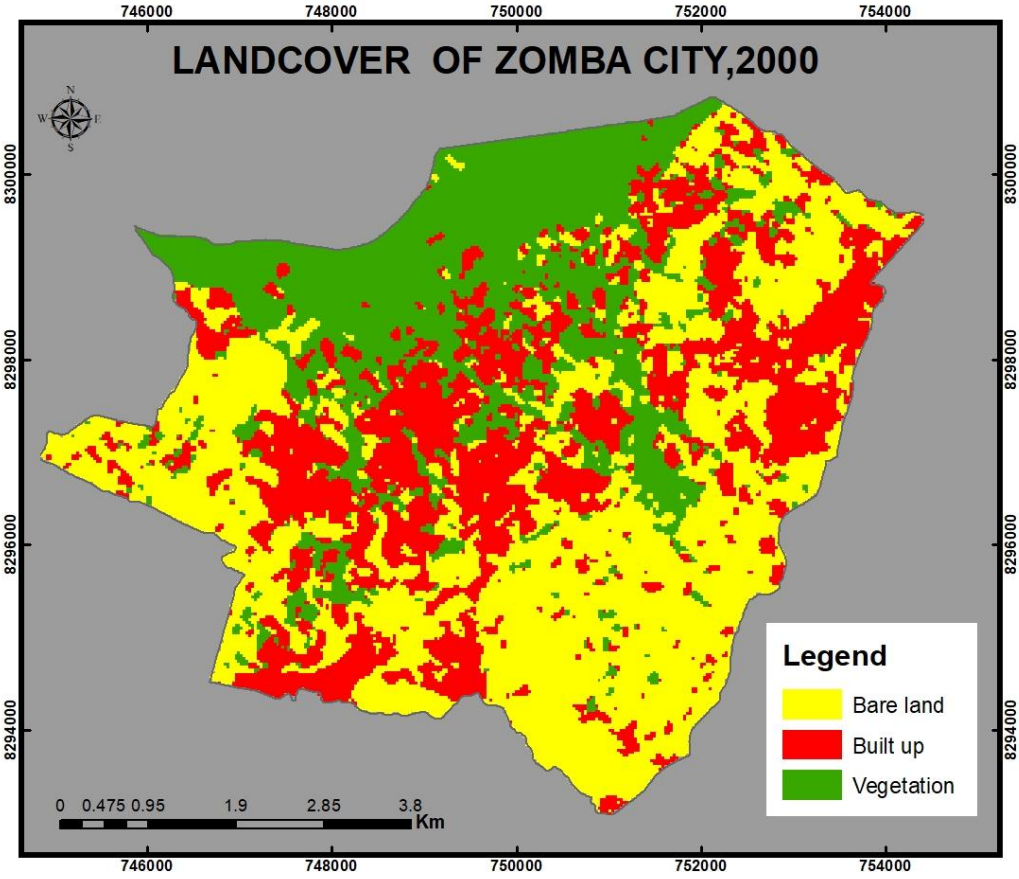


Figure 10: Land cover map of Zomba city in 2000.

Table 4: Showing area coverage in square kilometers for each landcover class

Zomba 2000

	FID	Shape *	Class_Name	Area
▶	0	Polygon	Bare land	18.252
	1	Polygon	Built up	12.4362
	2	Polygon	Vegetation	11.0763

The summary for the classification analysis of 2011 has been displayed in (Fig.11) which is showing the area coverage of each class based on percentage. Fig (12) is the Land cover map of the study area in 2011. The land area share was dominated by bare land (42.62%) followed by built up (32.98%). The remaining percentage is vegetation (24.40%).

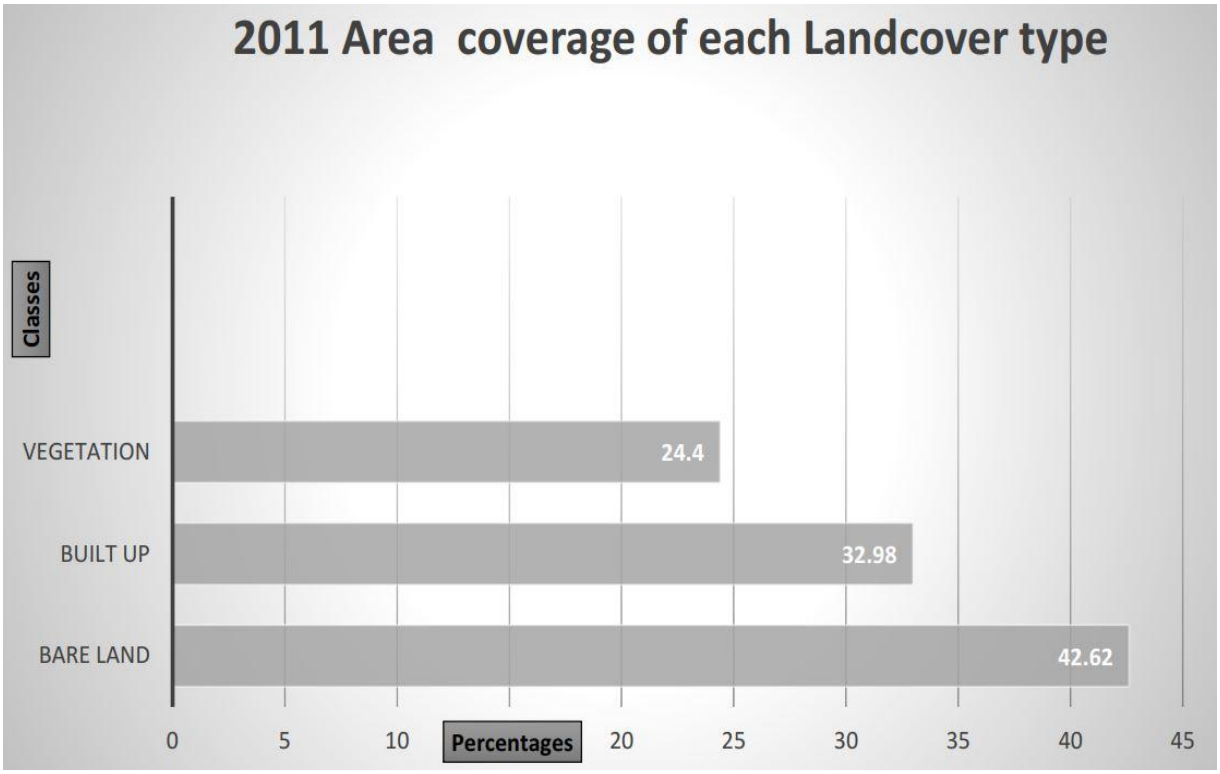


Figure 11:: Area covered by each Landcover type in 2011.

There is an increase in bult-up percentage coverage by 3.2% in 2011 while vegetation percentage coverage has decreased by 2.12%.

Table 5: Showing area coverage of each landcover type in 2011.

Zomba 2011

FID	Shape *	Class_Name	Area_sqkm
0	Polygon	Bare land [Thistle] 2250 points	17.7993
1	Polygon	Built up [Red] 1762 points	13.7727
2	Polygon	Vegetation [Green] 1092 points	10.1925

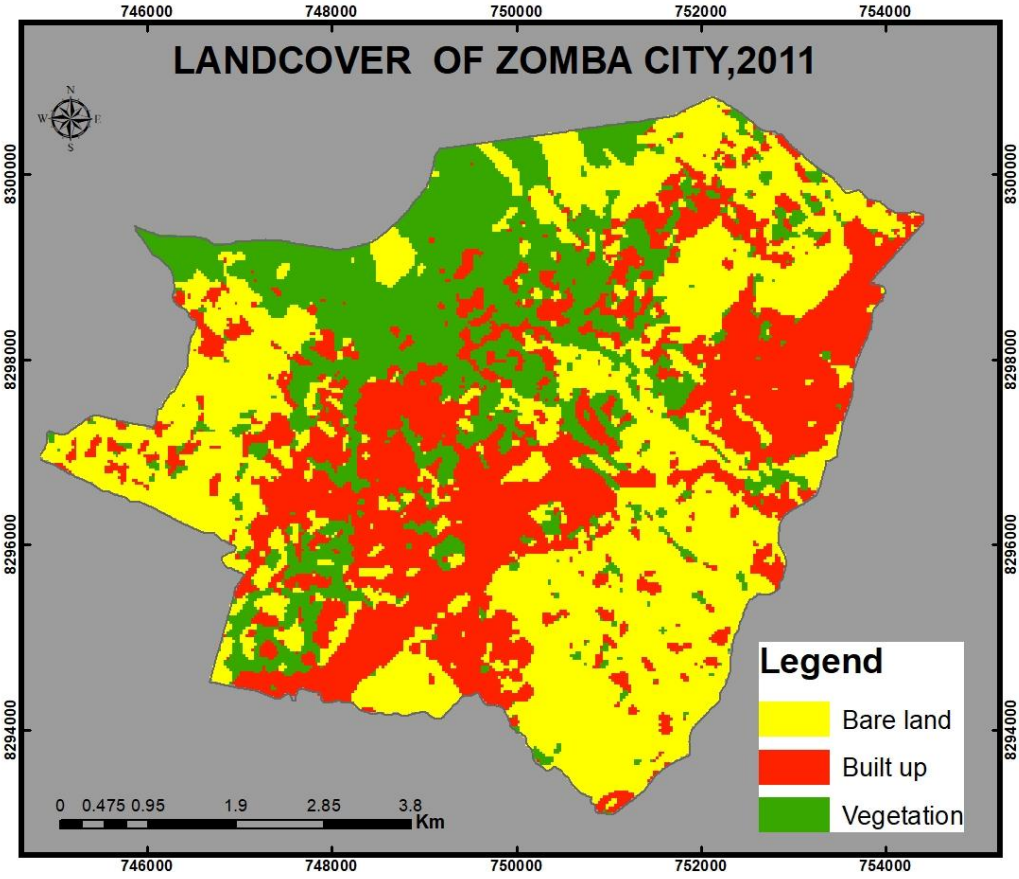


Figure 12: Landcover map of Zomba city in 2011.

The classification output for 2020 which represents the current situation of the study area shows that built up is dominating area and percentage coverage of Zomba city. The built-up land area shares accounts for 43.10%. Bare land has dropped to 35.60% while vegetation continues to be the last among the investigated classes with 21.32%.

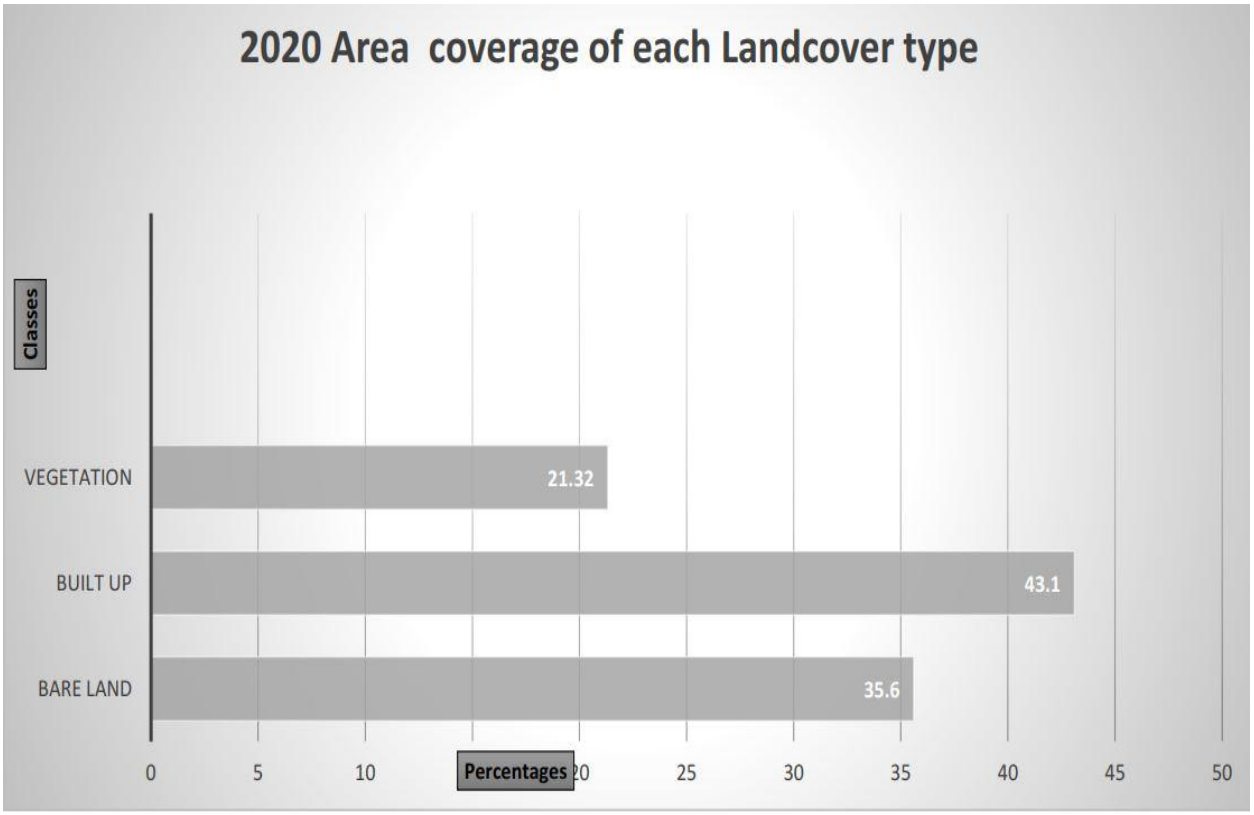


Figure 13: Area covered by each Landcover type in 2020.

Built-up has increased by 10.12% while vegetation has decreased by 3.08%. The area coverage difference between vegetation and built-up is 9.9001 sqkms. Below is the table summarizing the area coverage.

Table 6: Showing area coverage for each landcover class in 2020.

Zomba 2020

FID	Shape *	Class_Name	Area_sqkm
0	Polygon	Bare land [Thistle] 1601 points	14.8608
1	Polygon	Built up [Red] 1447 points	17.991
2	Polygon	Vegetation [Green] 1069 points	8.9001

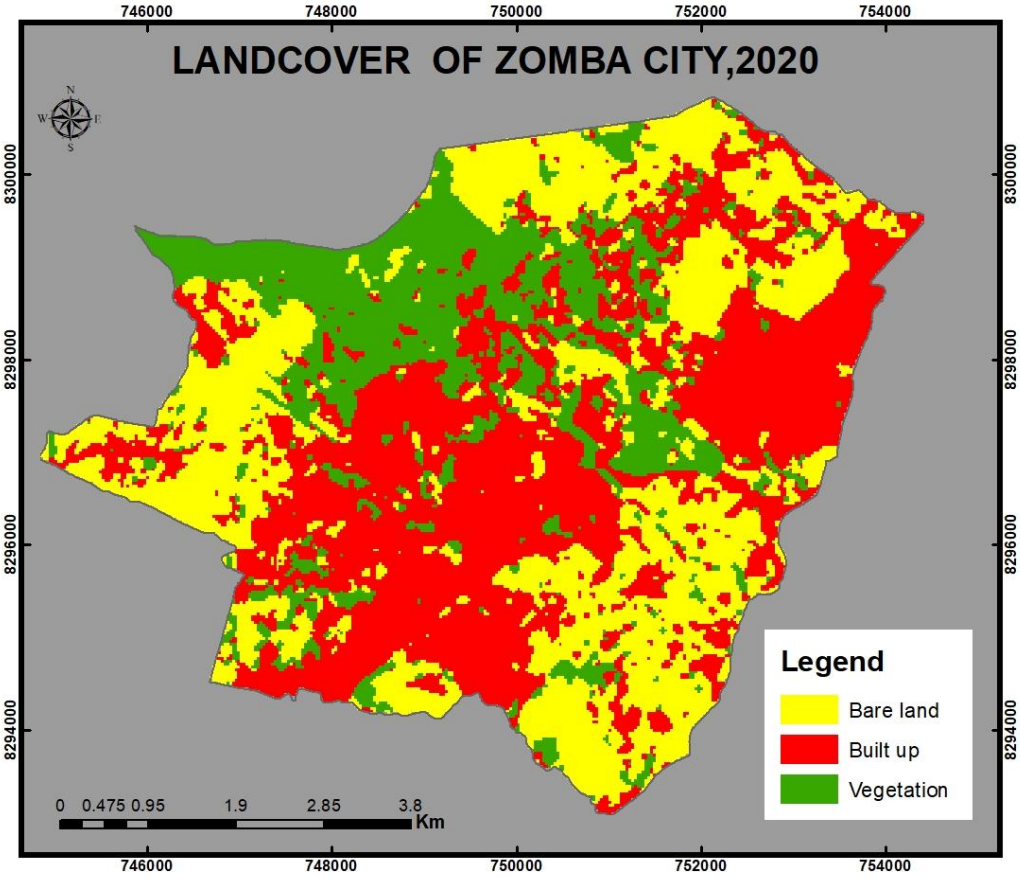


Figure 14:: Landcover map of Zomba city in 2020.

The current situation of the study area shows that area and percentage coverage of the built-up has rapidly increased thereby disturbing the coverage of vegetation class. Meanwhile, few wards namely: Mtiya, Zomba central and Likangala have dense vegetation content in some parts. This implies that those areas are not negatively affected, it has been observed that they are reserved and protected forests, urban gardens.

4.3.1 Change detection analysis

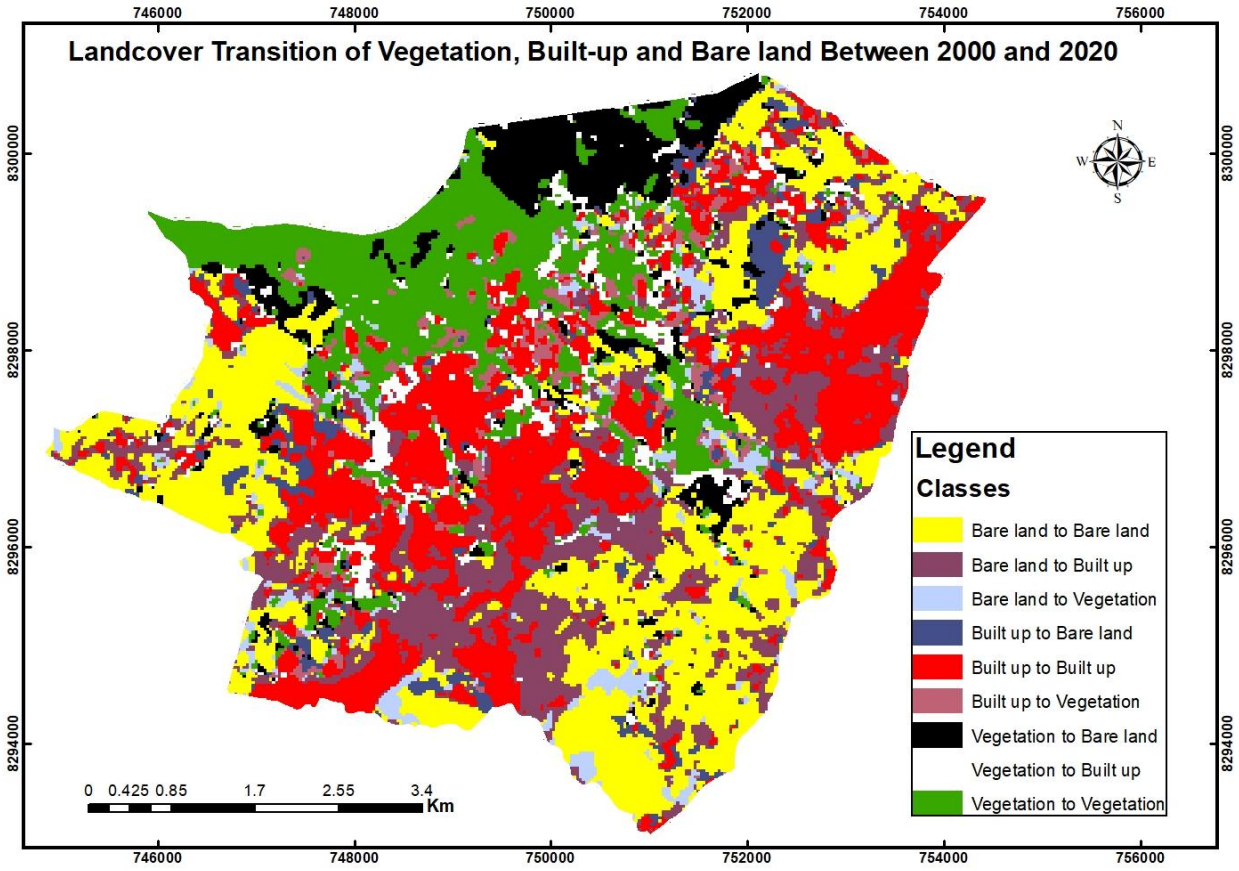


Figure 15: Transition map of Landcover types between 2000 and 2020

Landcover transition was dominated by bare land class. Bare land to built-up has transitioned by 7 sqkms over the years 2000 and 2020. It is seconded by built-up class and lastly vegetation. The transition of vegetation to bare land account for 3 sqkms whilst for vegetation to built-up is 2 sqkms. Below is the table indicating a summary of transition of the landcover types.

Table 7: Summary of the transition of each landcover type between 2000 and 2020

Union_2000_2020

FID	Shape *	FID_Zomba	Class_Name	Area	FID_Zombac	Class_Na_1	Area__sqkm	Area_trans
0	Polygon	0	Bare land	18.252	0	Bare land [Thistle] 1601 points	14.8608	10
1	Polygon	0	Bare land	18.252	1	Built up [Red] 1447 points	17.991	7
2	Polygon	0	Bare land	18.252	2	Vegetation [Green] 1069 points	8.9001	2
3	Polygon	1	Built up	12.4362	0	Bare land [Thistle] 1601 points	14.8608	2
4	Polygon	1	Built up	12.4362	1	Built up [Red] 1447 points	17.991	9
5	Polygon	1	Built up	12.4362	2	Vegetation [Green] 1069 points	8.9001	1
6	Polygon	2	Vegetation	11.0763	0	Bare land [Thistle] 1601 points	14.8608	3
7	Polygon	2	Vegetation	11.0763	1	Built up [Red] 1447 points	17.991	2
8	Polygon	2	Vegetation	11.0763	2	Vegetation [Green] 1069 points	8.9001	6

Landcover change analysis for the study have revealed great variations among different classes over the years (2000-2020). Change analysis are sensible for all the landcover types: bare land, built up, and vegetation. The summary of the variations has been represented in (fig.16). The results show that each class has an impact on other classes. It may either lead to the decrease or increase of the corresponding class. The domination of the shared area of the Zomba city have shifted from bare land to built-up class.

In 2000, bare land in Zomba city counted for 43.70% while in 2020 it was 35.60%. This indicate that bare land has decreased by 8.1%. While the bare land is decreasing, the built up is increasing rapidly due to high demand for houses in the city. Urbanization is one of the most important contributing factors to increase in built up. The built-up coverage by percentage was 29.78% in 2000,32.98% in 2011, and 43.10% in 2020 increased by 13.32%. Vegetation trend over the years has been decreasing as a result of the increase in built up class. It has dropped from 26.52% to 21.32% reduced by 5.2%.

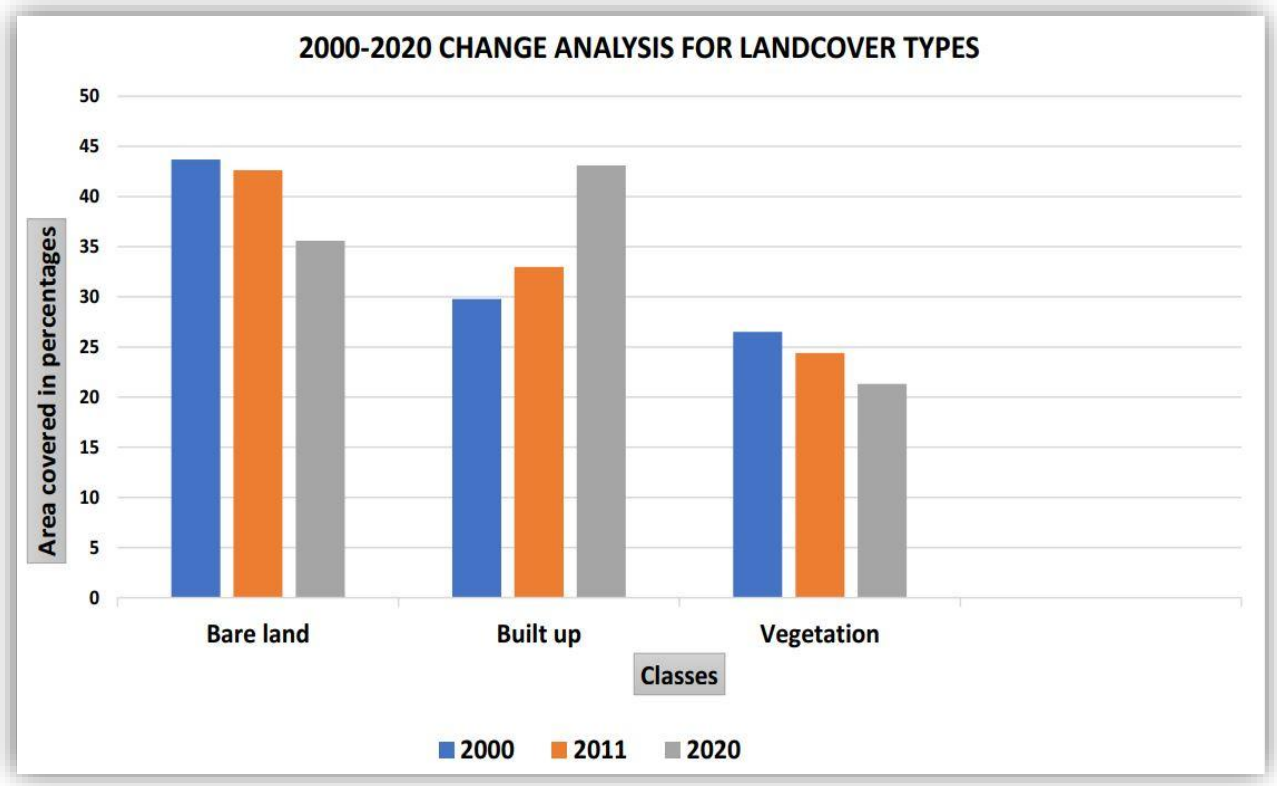


Figure 16: A graph showing 2000-2020 change analysis

4.3.2 Limitations of the study

i. Some of the satellite imagery data were not available. For example, the Landsat 5 TM covering the months of September-October,2010 was not available instead 2011 Landsat TM image was used thereby disturbing the preferred interval of 10 years.

ii. Some of the signatures were not clearly visualized. This led to missing out of including important classes e.g., water. There are inland water bodies within Zomba city: Domasi river, Mulunguzi dam, and Likangala river among others.

iii. Some of the decrease in percentage and area coverage of vegetation may not only be as the result of increase in built-up class.

4.4 Conclusion

GIS and its corresponding techniques were employed in this study and they have indicated to be one of the most important tools to use when detecting the change for particular phenomena under investigation. For this study Landcover maps were produced to distinguish different characteristics among Landcover types in Zomba city.

Zomba city is experiencing a reduction in vegetation cover and bare land while the built up is rapidly increasing. This change in vegetation coverage has been observed to be of significance. The study combined satellite image classification methods with modern GIS techniques to come up with comprehensive and concise Landcover maps that will benefit building construction managers, land use planners, and stakeholders to formulate and implement better decisions to reduce and manage negative building construction activities on vegetation. Meanwhile, the decrease in vegetation coverage space has also been observed to be as a result of several factors not only as a result of increase in built-up class. The other factors are bushfires around Zomba city. For instance, the scenario in Masongola and Mtiya ward. In Masongola ward it has been observed that bushfires around Chawe have influenced the decrease in vegetation coverage over the years.

For the analysis which has been carried out in Zomba city it recommended that people should replant trees which have been cut during building construction activities. As a fourth largest and young city in Malawi, Zomba should learn from other major and long-established cities in terms of city planning and vegetation conservation management. Furthermore, building construction managers and land use planners should follow best ways by taking better decisions and making better choices when building around the city. They should also promote urban gardens and improve building designs and methods. Recycling, re-using and reducing building materials and resources should be employed. At large build responsibly.

Finally, the experiences and knowledge gained from this study put forward some recommendations and solutions for future generations' studies. Higher resolution satellite images of both dry and wet season may produce healthy and strong results, particularly to deal with the challenges that Zomba city is encountering in terms of vegetation cover.

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