ANALYSIS OF URBAN GREEN SPACES AND POTENTIAL EXPANSION AREAS

A Case Study of Nyamagana District

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A Dissertation Submitted in the Department of Geospatial Sciences and Technology in Partial Fulfilment of the Requirements for the Award of Bachelor of Science in Geographic Information Systems and Remote Sensing (BSc. GIS & RS) of Ardhi University.

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University dissertation titled **"Analysis of urban green spaces and potential expansion areas, a case study of Nyamagana District"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geographical Information Systems and Remote Sensing at Ardhi University.

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I, SARAH TIMOTHY PAUL hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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SARAH TIMOTHY PAUL

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DEDICATION

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ABSTRACT

Urban green spaces are important components, contributing in different ways to the quality of human well-being. Due to increase in population mainly as a result of migration, these spaces have been on the verge of completely disappearing let alone their current deterioration. In the planning and management of urban centers, attention to the appropriate site selection of urban green spaces with regard to the importance that these spaces have from the perspectives of ecology, socioeconomic and mentality, is an inevitable requirement. Therefore, the aim of this study was to assess the impacts of urbanization on urban green spaces and selection of potential sites for green spaces expansion in Nyamagana District.

In this study, the methodology that was employed was land cover mapping for the assessment of change in urban and vegetation patterns as well as GIS-based Multi-criteria analysis (MCA) that has been adopted to select suitable sites for urban green spaces expansion. Population density, scenic attractiveness, slope, elevation and 2021 land cover map were recognized as the key factors affecting urban green land suitability.

The results of this study show that the percentage coverage of urban class has been increasing from 7.52%, 12.55% and 21.06% in 2015, 2018 and 2021 respectively. As urban class coverage was increasing, vegetation coverage was decreasing rapidly where its percentage coverage was 21.43%, 10.25% and 5.98% in 2015, 2018 and 2021 respectively. This actually means that urban class is increasing at the expense of vegetation and urban green spaces. In Multi-criteria analysis, few places were seen to be highly suitable and unsuitable with a percentage coverage of 6.13% and 4.3% respectively. Suitable and moderately suitable areas with 20.4% and 12.6% respectively while large coverage of the area was poorly suitable with 57.4%.

The conclusion of the research is that urban class has increased at a high rate while vegetation has decreased at a high rate as well. This is to say, urbanization has increased at the expense of urban green spaces. Also, from the multi-criteria analysis results, there are areas that are suitable for the expansion of urban green spaces and this is to say, there is still room for experiencing the benefits of urban green spaces once they are expanded or new ones are created. The recommendation of this research is that ground data should be used to identify the types of green spaces that can be created and expanded and the actual size that is required for the green spaces.

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ACRONYMS AND ABBREVIATIONS

GIS	Geographic Information System
RS	Remote Sensing
GEE	Google Earth Engine
USGS	United States Geological Survey
SRTM	Shuttle Radar Topography Mission
DEM	Digital Elevation Model
OLI	Operational Land Imager
UGS	Urban Green Spaces
AHP	Analytical Hierarchy Process
URT	United Republic of Tanzania
MCA	Multi-Criteria Analysis

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Urban green spaces, characterized by abundant vegetation, encompass a diverse array of outdoor areas within cities. These spaces encompass semi-natural landscapes, thoughtfully managed parks, and carefully cultivated gardens. They also extend to include pockets of greenery interspersed along roads and incidental locations (Jim and Chen, 2003).

The significance of urban green spaces extends far beyond their aesthetic appeal, as they bestow substantial physical, social, and mental health benefits upon city residents. In the modernized urban world, these spaces have assumed a pivotal role by serving as essential providers of ecosystem services. They contribute to enhancing the quality of life for urban inhabitants through functions like runoff control, air purification, and even the mitigation of global climate change. Urban green spaces, furthermore, offer a realm of opportunities for individuals, affording the places for physical activities, fostering social connections, enabling interactions with nature, and fostering a sense of connection to cultural heritage sites (Au et al., 2019).

In the Tanzanian context, urban green spaces are defined as regions within urban areas that encompass grass, trees, shrubs, and other forms of vegetation (URT, 2016). Despite the pronounced advantages linked with urban green spaces, Tanzanian urban dwellers face challenges in experiencing these benefits. This quandary arises due to an interplay of factors, with prominent contributors being increased urbanization, unplanned urban expansion, and the absence of careful site selection for green spaces. The issue of urbanization warrants particular attention, as it has precipitated an increase in unplanned settlements across various locales, including Nyamagana District in the Mwanza region. This phenomenon is rooted in a combination of population growth and migrations from different parts of the country. The consequential strain on natural resources and the environment is undeniable. An upshot of this growing demand for space is the increasing utilization of land for infrastructural development and construction, eroding the availability of urban green spaces.

In the face of growing urbanization, it is imperative to underscore the integration of urban green spaces within the framework of urban planning and management. Their indispensability is rooted in their various roles, spanning ecological, socioeconomic, and psychological dimensions. As urban landscapes evolve, a conscientious approach that factors in the preservation and expansion of urban green spaces becomes imperative (Mensah, 2014). Central to this endeavor is the application of comprehensive land suitability analysis. By assessing the suitability of diverse sites, this analysis facilitates the informed selection of the most appropriate locations for expanding urban green spaces. In the context of rapidly expanding cities like Nyamagana District, the integration of green spaces within urban planning acquires heightened importance.

In this light, this research seeks to explore, analyze, and propose strategies for optimizing urban green spaces in a rapidly urbanizing context. By investigating the potential expansion areas and crafting a robust framework for their inclusion, this study aims to contribute to the sustainable development and well-being of urban communities. The research endeavors to bridge the gap between the pressing need for urban development and the preservation of essential green spaces, harmonizing the growth of human settlements with the imperative of maintaining a balanced and healthy urban environment

1.2 Statement of research problem

Mwanza is a port city on the shore of Lake Victoria, in north-western Tanzania and it is the second busiest and largest city in Tanzania. It contains 8 districts, where according to the 2022 census results, Nyamagana is the most populated district in Mwanza, and is facing a number of development challenges especially the rapid urbanization rates and unguided urban expansion. Some of the development challenges are unplanned putting pressure on natural resources. One of the resources that are in a threat of deteriorating is urban green spaces. This study aims at assessing the impacts that urbanization has brought on urban green spaces as a precursor to planning for sustainable community and cities.

1.3 Objectives of the study

1.3.1 Main Objective

- Assessing the impacts of urbanization on urban green spaces in Nyamagana District and identifying suitable areas for their expansion.

1.3.2 Specific Objectives

- To quantify the temporal evolution of urban green spaces and their relationship to urbanization patterns using land cover maps from the years 2015 to 2021.
- Identification of potential urban green spaces expansion areas using multi-criteria analysis.

1.4 Research Questions

- How have patterns of urban green spaces and urbanization changed from the year 2015 to 2021?
- Are there potential areas for future expansion of urban green spaces in Nyamagana District?

1.5 Rationale of the study

The significance of this study is to show how urbanization is continuously threatening urban green spaces by assessing their current state in terms of size and quality and also to assist in planning because of the multi-criteria analysis methodology that can be a guide in the expansion of urban green spaces. The study also contributes to the United Nation's sustainable development goals specifically the sustainable cities and communities goal where it is identified by the United Nations that as city authorities work to redesign and retrofit the spatial configuration of urban areas, it is important to consider the distribution of green areas (Sustainable & Goals, 2022). This study can be a guide in identifying areas that can be used for expanding existing urban green spaces in Nyamagana District and also creating new ones since it is a growing and strategic city, in order to promote sustainable urban development.

1.6 Beneficiaries of the research.

- Researchers

This research will be of help to other researchers because they can use it as a starting point to other studies of their own or they can proceed from the outcomes of this research to conduct another study.

- City residents

This research will help to inform decision making around the planning and design of these urban green spaces, leading to improved outcomes for the residents.

- Government

This research can be of importance to the government to make informed decisions about how to allocate resources and prioritize investment in potential areas for urban green spaces expansion.

- Environmental organizations

The research can be beneficial to environmental organizations because they can help to raise awareness about the need for more urban green spaces in the city and also the need for better planning and design of these spaces.

1.7 Scope and Limitations of the Research

The study focuses on quantifying the temporal evolution of urban green spaces and their relationship to urbanization patterns in Nyamagana District by using land cover maps and also by using GIS-based multi-criteria analysis, potential expansion areas were identified where various thematic layers and criteria were used to achieve this. Due to data restraints, this study is limited to only five factors for multi-criteria analysis in identifying potential areas for urban green spaces expansion and also, the study has not been able to identify the exact types of urban green spaces that should be in the expanded areas as well as their sizes.

1.8 Dissertation Structure

The research was carried out over a 15-week period during the second semester of the final year of studies, with the last two weeks dedicated to final presentations and it consists of 5 chapters that explain the analysis of urban green spaces and their potential expansion zones so as to assess the changes in pattern of these spaces and the areas that can be suitable for expansion of existing ones and creation of new ones using land cover maps and multi-criteria analysis respectively.

Chapter 1

This chapter involves introduction of the research and this is by describing relevant background information, the problem statement of the research, the objectives, significance, beneficiaries, scope and limitation to show the extent of the research on the objectives provided as well as the research questions that are derived from the objectives.

Chapter 2

The Literature Review chapter describes information obtained from several literatures about urban green spaces globally, in Africa and in Tanzania as well as the approaches that will be used in achieving the outputs.

Chapter 3

This chapter describes the methodology utilized to achieve the research objectives, and a flow chart that is a guide on how the outputs of the research were achieved. It explains all the methods that were used in the research from data collection, data pre-processing as well as data processing.

Chapter 4

This is the results, analysis and discussion chapter, which provides details on the valuation of the research findings basing on the objectives through the use of maps and the graphs that have been generated in the study.

Chapter 5

This chapter contains the conclusions and recommendations. It gives a conclusion based on the research objectives and recommendations, based on the research findings.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter reviews different studies that have explored urban green spaces, their deterioration and expansion. It involves gaining an insight on several studies that have discussed the suitability of land in expansion of urban green spaces as well as the methods they have gone about and also studies that have explored the analysis of green spaces deterioration and the methods used to go about it.

2.3 Urban green spaces perspective in Africa

Urban green spaces in Africa encompass both public and private open areas within urban settings, predominantly covered by vegetation. These spaces, such as parks, gardens, wetlands, and urban trees, offer direct (e.g., recreation) or indirect (e.g., positive impact on the urban environment) benefits and are essential for various purposes (Mensah, 2014).

However, alarming statistics indicate that urban green spaces in Africa are rapidly diminishing, with only a small proportion of landmass in several urban areas now occupied by green spaces. Planning concepts like the garden city, green belt, green fingers, and greenways have emphasized the need to incorporate ample green spaces into city designs to preserve the natural environment and unlock the immense benefits they provide (Mwansa, n.d.).

From a social perspective, green spaces contribute to recreational opportunities, support child development, and facilitate social interaction. Environmentally, they improve local climate, urban air quality, and biodiversity conservation, while also enhancing the aesthetic appeal of cities. Economically, green spaces boost property values, create employment opportunities through park-related jobs and businesses, and generate revenue to support government expenditure(Gelan, 2021). Despite these advantages, studies in African countries reveal intense pressure on green spaces due to various human activities, resulting in their persistent deterioration, particularly in urban areas where the pressure is more pronounced (Cilliers & Cilliers, n.d.).

Currently, the rapid depletion of green spaces in Africa has led to their occupancy of a minimal percentage of total land in many urban areas. For instance, several towns in the Republic of South Africa have less than 10 percent of their land dedicated to green spaces, and in Lagos, Nigeria, green spaces occupy less than 3 percent of the land (Mensah, 2014). Research on urban green spaces, particularly focusing on the challenges they face, is limited in Africa. While existing studies often concentrate on specific cities, they indicate that the overall development of urban green spaces in Africa is hindered by numerous challenges, including urbanization, inadequate institutional resources, low prioritization of green spaces, poverty, corruption, uncooperative attitudes of local communities, and political instability (Lategan & Cilliers, 2014).

2.2 Urban green spaces as a global perspective

Urban green spaces encompass various forms of vegetation within the urban environment, such as parks, open spaces, residential gardens, and street trees (Reinwald et al., 2021). The global urban population is projected to rise from 50% in 2010 to nearly 70% by 2050, leading to the expansion and densification of urbanized areas (Sustainable & Goals, 2022).

However, the increasing number and density of urban residents have resulted in over-urbanization and numerous challenges. These challenges include widening social inequalities, limited access to public amenities, and a relative disregard for environmental aspects, all of which threaten the livability of cities (Reinwald et al., 2021).

Despite ongoing migration to urban areas, the importance of sustainable urban development is growing, making the planning and management of urban green spaces crucial. These spaces provide essential benefits to urban dwellers and serve as vital habitats for wildlife. Urban green spaces are multifunctional, serving purposes such as facilitating social interaction, enhancing aesthetics, preserving cultural heritage, providing recreational opportunities, and supporting ecological functions (Yu et al., 2020).

Recognizing the ecological functions and the importance of biodiversity conservation in urban areas, urban green spaces play a critical role in air purification, water and climate regulation, carbon storage, storm water management, and noise reduction from road traffic, acting as natural air filters (Pedrosa et al., 2021)).

However, despite regional variations in urban density, population growth, and societal conditions, several recurring challenges arise from the compact city approach and densification processes. These challenges include the loss of public and private urban green spaces due to densification measures, insufficient provision of green spaces in areas undergoing densification, and the risk of quality degradation in existing green areas (Korn, n.d.).

2.4 Urban green spaces in Tanzania

Tanzania is recognizing the need to restore green spaces in its urban areas, which have been gradually replaced by buildings and infrastructure over the years. Although there is limited research on urban green spaces in Tanzania, particularly in Dar es Salaam, existing studies shed light on the effects of urbanization on these spaces. The continuous and seemingly boundless expansion of urban areas is taking its toll on Dar es Salaam, Tanzania's future megacity and commercial capital, with an estimated 1,000 new residents arriving daily. By 2030, the city is projected to house a population of over 10 million (Makoye, 2020).

Rapid urbanization and associated urban sprawl pose constant threats to public spaces, which are increasingly disappearing from the urban fabric. It's not just the quantity of public space that is affected, but also the quality in terms of usefulness to citizens and ecological services provided. Open areas often become barren patches of sand, lacking trees and the attractiveness and diverse functions necessary for inclusive public use (Marrewijk, 2019).

In 2004, Dar es Salaam lagged behind other African cities in terms of providing green space for its population. While other cities in the region offered an average of $74m^2$ of open space per capita, Dar es Salaam only provided $64m^2$. Additionally, the city witnessed a decline of over 10% in tree cover annually between 2002 and 2008. Presently, as little as 2% of Dar es Salaam is classified as public greenspace (Dickson, 2019).

To enhance the livability of Tanzania's commercial capital, the World Bank, through the Dar es Salaam Metropolitan Development Project, is supporting crucial investments in infrastructure, community upgrading, urban planning, and capacity building. One of these initiatives is the Dar Open Spaces Upgrading, which aims to improve several open spaces for inclusive recreational use while strengthening the city's green infrastructure. These efforts are crucial in rejuvenating and preserving the much-needed green spaces in Dar es Salaam (Dickson, 2019).

2.5 Determination and rating of criteria for multi-criteria analysis

This is a crucial stage in multi-criteria analysis and it involves determining and selecting the criteria that are required for multi-criteria analysis (MCA). There are still no agreed universal criteria and factors for urban green spaces planning, however, by synthesizing literature review as well as previous related studies conducted by different researchers, some factors were considered for the suitable site for the development of these spaces. The factors and criteria used in this research were population density, slope, elevation, visibility and land cover map (Gelan, 2021).

Table 2.1 Summary of factors, criteria and their suitability ratings

Factors	Criteria	Standardization score	Factor suitability rating
Population density	PD>5000persons/sqkm	5	Highly suitable
		4	Suitable
		3	Moderately suitable
		2	Poorly suitable
		1	Unsuitable
Slope	Slope < 15%	5	Highly suitable
		4	Suitable
		3	Moderately suitable
		2	Poorly suitable
		1	Unsuitable
Elevation	Elevation < 1200m	5	Highly suitable
		4	Suitable
		3	Moderately suitable
		2	Poorly suitable
		1	Unsuitable
Visibility	Visibility > 3	5	Highly suitable
		4	Suitable
		3	Moderately suitable
		2	Poorly suitable
		1	Unsuitable

2.6 Terms used in the research

2.6.1 Geographical Information Systems (GIS)

Geographical Information Systems (GIS) is a powerful technology that encompasses the capture, storage, analysis, and visualization of spatial data, combining different data types like maps, satellite imagery, aerial photos, and tabular data (Huisman & By, n.d.). It allows users to create digital maps, manipulate and interpret geographic information.

GIS has a capability of performing various tasks such as (Goodchild, 1994):

- Data Capture - GIS facilitates the collection of geographic data using methods such as satellite imagery, GPS and digitization of paper maps.
- Data Storage and Management - GIS systems efficiently store and manage large volumes of geospatial data in databases, ensuring their easy access, updates and sharing.
- Spatial Analysis - GIS tools perform spatial analysis operations like layer overlay, buffering, proximity analysis, and modeling that enables gaining insights and informed decision-making.
- Visualization and Mapping - GIS provides tools for creating maps and visually representing geospatial data, facilitating effective exploration and communication.
- Decision Support - GIS supports decision-making by providing spatially-informed analysis and modeling, helping understand the potential impacts on the environment, infrastructure, or communities.

Other than the tasks it performs, there are also advantages of GIS that include (Code, n.d.):

- Improved Decision-Making: GIS provides spatial context and analysis capabilities, aiding informed decisions by identifying patterns and relationships.
- Enhanced Data Management: GIS organizes and integrates geospatial data, ensuring consistency, accuracy, and enabling data sharing and collaboration.
- Spatial Analysis and Modeling: GIS offers a range of techniques for analyzing and modeling spatial phenomena, aiding in understanding and prediction.
- Improved Efficiency and Productivity: GIS streamlines data collection, analysis, and visualization processes, enhancing productivity.
- Enhanced Communication and Visualization: GIS enables clear communication of complex geospatial information through maps and visualizations.
- Emergency Response and Situational Awareness: GIS plays a critical role in assessing risks, identifying vulnerable areas, and coordinating emergency operations.
- Cost Savings and Resource Optimization: GIS enables cost-effective decision-making through optimized resource allocation and identifying areas for improvement.

2.6.2 Remote Sensing

Remote sensing involves acquiring information about objects, areas, or phenomena without direct physical contact. It utilizes sensors mounted on satellites, aircraft, or drones to capture data from a distance by detecting electromagnetic radiation, such as visible light, infrared, or microwave wavelengths (Sensing, n.d.).

There are several reasons for employing remote sensing (Curran, 1995):

- Wide coverage - Remote sensing enables data collection over large and inaccessible areas, particularly remote or hazardous environments where direct observation is impractical or unfeasible.
- Spatial and Temporal resolution - Remote sensing allows information to be captured at different spatial scales, ranging from global to local levels. It also permits repeated data acquisition over time, facilitating the monitoring of changes and trends in landscapes, ecosystems, and other phenomena.
- Multispectral and Multi-temporal data - Remote sensing provides data in multiple spectral bands, enabling analysis of various properties and characteristics of objects or areas. It also enables the comparison of data acquired at different times, aiding in the detection of temporal variations and patterns.
- Non-destructive data collection - Remote sensing techniques collect data without direct contact or disruption to the studied object or area. This non-destructive nature is valuable for monitoring sensitive environments or studying difficult-to-access objects.
- Cost and efficiency - Remote sensing can be a cost-effective method compared to traditional ground-based surveys or direct measurements. It allows for the collection of a large amount of data over extensive areas within a relatively short timeframe, reducing time and resource requirements.
- Integration with GIS and analysis - Remote sensing data can be integrated with Geographical Information Systems (GIS) to analyze and visualize the captured information in a spatial context. This integration enhances interpretation, modeling, and understanding of various phenomena.

Remote sensing was very useful in this research for obtaining land cover maps that show the changes and development of Nyamagana District by using Landsat 8 OLI images which are obtained remotely.

2.6.3 Image classification

Image classification is defined as the process of categorizing all pixels in an image or raw remotely sensed satellite data to obtain a given set of labels or land cover themes (Rujoiu-Mare & Mihai, 2016). Image classification is an essential undertaking that seeks to understand an entire image as a cohesive unit. Its objective is to assign a specific label to the image as a means of classification There are two broad types of classification procedures which are supervised image classification and unsupervised image classification.

i. Image classification types

- Unsupervised image classification

This is an image classification method in which the image interpreting software separates a large number of unknown pixels in an image based on their reflectance values into classes or clusters with no instruction from the analyst (Rujoiu-Mare & Mihai, 2016). The fact that samples are not needed for unsupervised classification, makes it an easy way to segment and understand an image hence, is the most basic classification technique.

- Supervised image classification

Supervised image classification involves the analyst defining small areas called training sites or samples on the image that contain predictor variables that are measured in each sampling unit, and assigns prior classes to the sampling units (A. L. Use & Anderson, 2017).

It involves training a classification algorithm using labeled examples, where input images are associated with specific class labels. By learning from this labeled dataset, the algorithm gains the ability to accurately classify new and unseen images.

Why supervised image classification?

In the case of this research, supervised classification was chosen as the image classification type due to the need for high accuracy in land cover classification and the advantage of increased control it offers. Supervised classification involves training a classification algorithm using labeled examples, where input images are associated with specific class labels (Rujoiu-Mare & Mihai, 2016).

This process allows the algorithm to learn from the labeled dataset and develop the ability to accurately classify new and unseen images. Before the actual classification takes place, a significant amount of preparation is required. The outcome of the classification process is a thematic image where the classes are labeled, representing various information classes or land cover types (Huisman & By, n.d.).

While supervised classification tends to be more accurate than unsupervised classification, its effectiveness is influenced by factors such as the selection of training sites, the expertise of the person processing the image, and the spectral distinctiveness of the classes. Misclassifications are more likely to occur if two or more classes exhibit similar spectral reflectance

ii. Image classification algorithms

An image classification algorithm is a computational method or technique used to automatically classify images into different predefined categories or classes. These algorithms analyze the visual features and patterns present in images to make accurate predictions about their content or characteristics (Classification, n.d.). There are various image classification algorithms such as Maximum Likelihood, Minimum Distance, Principal Components, Support Vector Machine, Random Forest and Iso Cluster but for this research, the classification algorithm used was Random Forest.

2.6.4 Random Forest

The random forests algorithm is a powerful machine learning technique increasingly utilized for image classification. As an ensemble model, it combines the results of multiple models to generate a response, often yielding superior outcomes compared to individual models (Zhang et al., 2021). In the case of random forests, numerous decision trees are created, and the response is determined based on the collective outcomes of all the decision trees.

To comprehend how random forests work, familiarity with decision trees is necessary. Decision trees are predictive models that employ binary rules to calculate a target value. There are two types: classification trees, used for categorical datasets like land cover classification, and regression trees, used for continuous datasets like biomass and percent tree cover (A. L. Use & Anderson, 2017).

Random forests address the limitations of single decision trees while retaining their benefits, particularly for classification problems. The model generates a response variable, such as land cover, by constructing multiple decision trees. Each object, in this case, a multi-layered pixel, is passed down each decision tree, and the response is determined by aggregating the results from all the trees. The class predicted most frequently becomes the assigned class for that object (Horning, 2010).

When running random forests, several parameters need to be specified. Common parameters include input training data, the number of trees to build, the number of predictor variables for each split, and parameters for calculating error information and variable significance (Box, n.d.).

Random forests offer several advantages over other machine learning algorithms like support vector machines. They are less sensitive to parameter settings, making it easier to determine suitable parameters (Nilsson, 2005). Additionally, random forests automatically provide accuracy measures, variable importance, and information about outliers, making them user-friendly and effective for analysis.

2.6.5 Land cover mapping

Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures (Cihlar, 2000). Land cover mapping is the process of classifying and delineating different types of land cover such as urban areas, bare land, vegetation and water bodies that are found within a specific region. The goal of land cover mapping is to generate accurate and detailed information about the spatial distribution and extent of different land cover types in a given area and it establishes a baseline from which monitoring such as change detection can be performed (A. L. Use & Anderson, 2017).

2.6.6 Weighted overlay analysis

Weighted overlay analysis is a spatial analysis technique used in GIS to combine and analyze multiple raster or vector datasets. It involves assigning different weights to each layer to reflect their respective significance or impact on the final result. By multiplying the values of each layer with their corresponding weights, a composite output layer is created, representing a weighted combination of the input layers (Zafar et al., 2022).

The resulting composite output layer accounts for the collective influence of the input layers, considering their relative importance. This layer serves the purpose of identifying areas with varying levels of suitability or potential based on the weighted criteria(Janssen, 2001).

Weighted overlay analysis was used in this research because it is a powerful approach that integrates multiple geospatial datasets, considering their relative significance, and produces a comprehensive output layer and its application is contributory in facilitating spatial decision-making and analysis (Cortes et al., 2022).

2.6.7 Multi-criteria analysis

Multi-criteria analysis is defined as a decision making approach that helps in evaluating and comparing multiple alternatives based on various criteria or objectives and it is designed to handle situations where there are conflicting objectives. It provides a systematic framework for evaluating alternatives and ranking them based on the chosen criteria (Ravilious, 2015).

Multi-criteria analysis methods can range in complexity as well as in sophistication where they can vary from simple techniques such as the weighted sum model to even more advanced approaches including the Analytical Hierarchy Process (AHP) and the choice of what method to use can depend on the available data, specific context as well as the decision maker's preference (A. Use et al., 2003).

2.6.8 Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a method used for multi-criteria decision making that was developed by Thomas L. Saaty in the 1970s, and it provides a structured approach for quantifying and analyzing complex decision problems involving multiple criteria as well as alternatives.

The choice of AHP method in this research is because it is capable of breaking down a decision problem into a hierarchical structure that consists of a goal, criteria and alternatives. The goal is the main or ultimate objective or the decision that is to be made, criteria are the factors that contribute to the decision and alternatives are the choices or options that are available for the evaluation (Mat et al., 1987).

AHP also provides a structured and systematic approach for decision making by incorporating both qualitative judgments and quantitative analysis. It also helps decision makers clarify their preferences, capture the relative importance of criteria and arrive at a rational decision based on logical framework.

AHP is performed in three steps, the first step being pair-wise comparison of criteria where the results are put into a comparison matrix. In the pairwise comparison, a higher level of scale shows a higher importance than the previous lower level (Munda, n.d.).

Values in the matrix are required to be consistent meaning that if X is being compared to Y, it receives a strong importance with a score of 9. Y being compared to X receives a little importance and Y or X being compared to itself, receives an equal importance with a score of 1 (Munda, n.d.).

Second step is the calculation of criterion weights and this is done by normalizing eigenvalue of the ratio matrix. It involves summing the values in each column of the pairwise comparison matrix, dividing each element in the matrix by the column total, where the resulting matrix is referred to as the normalized pairwise comparison matrix. The last procedure is computing the average of the elements in each row of the normalized matrix and this is by diving the sum of the normalized scores for each row by the number of criteria(Making, n.d.).

The calculation of consistency ratio (CR) is the third step that it is performed to identify inconsistencies and to develop the best weights in the complete pairwise comparison matrix and it involves using the following formula (Bunruamkaew & Yuji, 2001).

$$CR = \frac{\mathrm{CI}}{RI} \text{ .... Eqn (2.1)}$$

Where CR = Consistency ratio, CI = Consistency index and RI = Random inconsistency index.

The consistency index (CI) is obtained by the formula:

$$CI = \frac{\lambda \max - n}{n-1} \text{ .... Eqn (2.2)}$$

Where n = the number of items being compared in the matrix, λmax = average value of the consistency ratio.

2.6.9 Reclassification

Reclassification is defined as the process of taking input cell values and replacing them with new output cell values. Reclassification is used to simplify or change the interpretation of raster data by changing a single value to a new value or grouping ranges of values into a single value based on specific criteria or rules (Huisman & By, n.d.).

It is a powerful GIS tool that is often used to simplify data, aggregate categories or create new thematic representations of a dataset and is commonly used in suitability analysis, data aggregation, thematic mapping and land cover classification (Code, n.d.).

CHAPTER THREE

METHODOLOGY

3.1 Overview

Research methodology implies the way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. In methodology we study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them. It is necessary for the researcher to know not only the research methods or techniques but also the methodology.

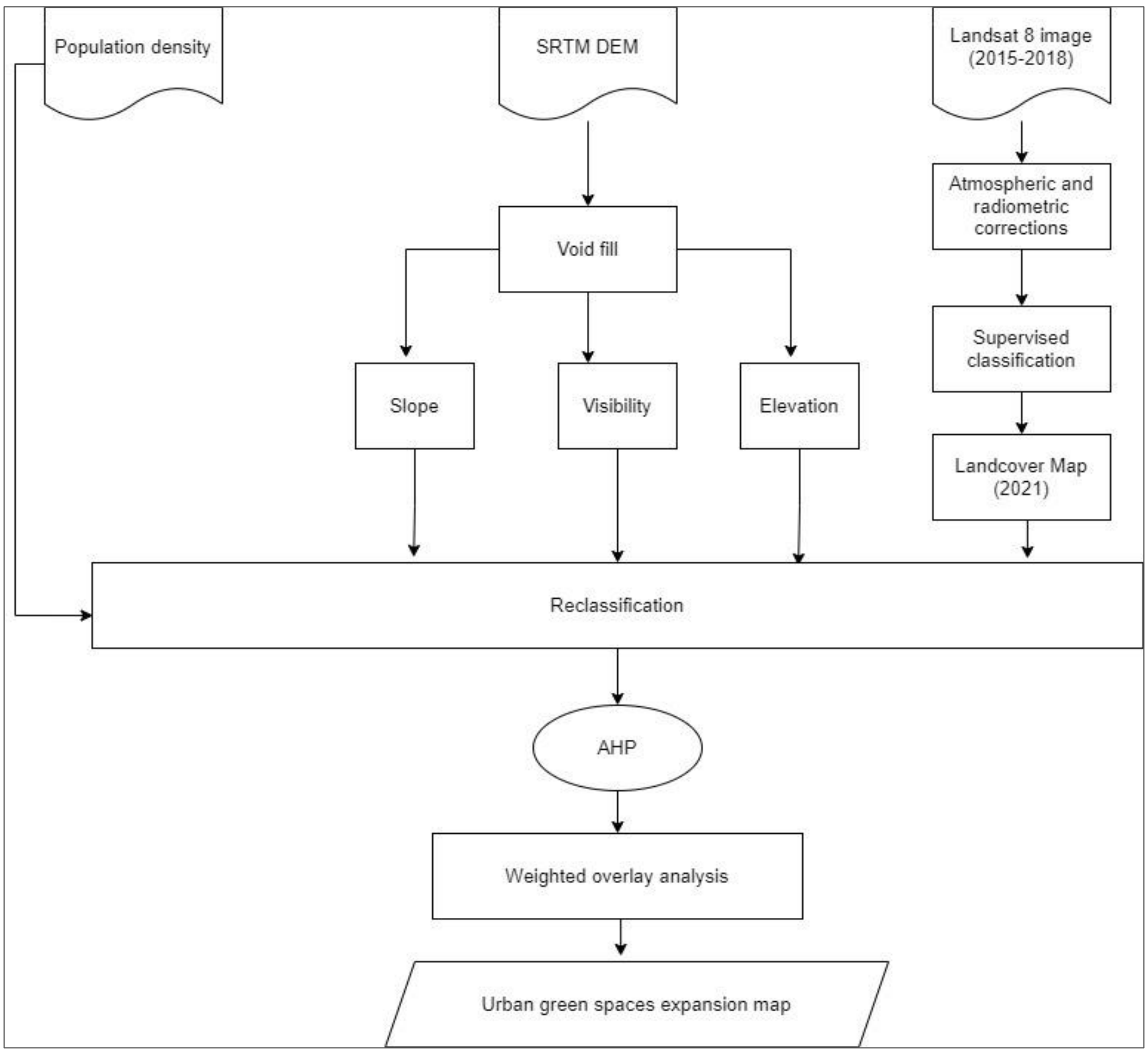

Figure 3.1 Methodological flowchart

3.2 Description of the study area

Nyamagana District is one of the seven districts in Mwanza region that stretches between coordinates 02^{0} 35'S and 032^{0}55'E to 02^{0}50'S and 033^{0}04'E covering a total area of about 182.7 square kilometers containing a total of 12 wards, a population of 594,834 and it is known to be the most urbanized district. Being the most urbanized district, Nyamagana is characterized by settlement growth both formal and informal that is associated with the construction of new buildings and infrastructures resulting to the deterioration of urban green spaces.

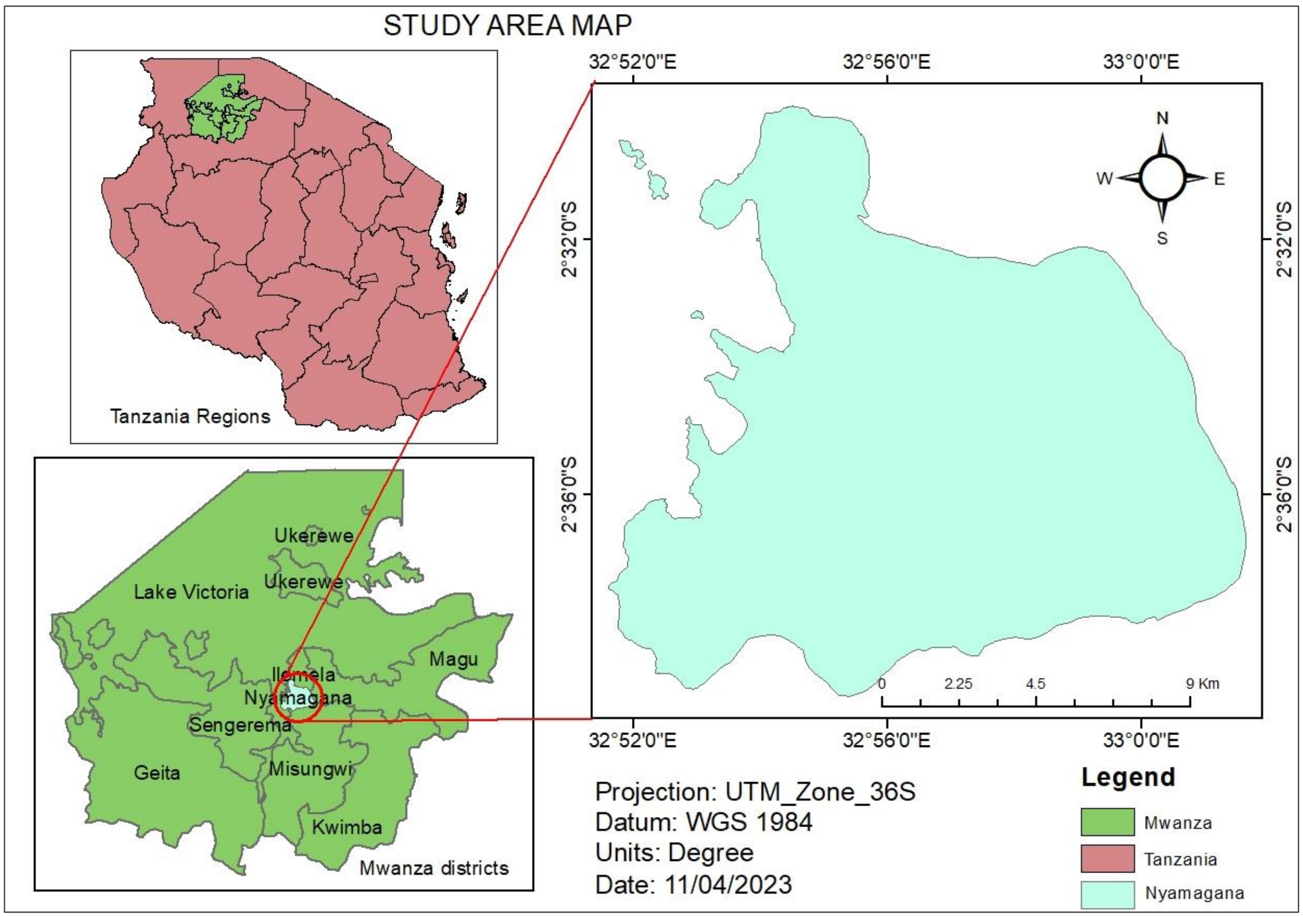

Figure 3.2 Study area map

3.2 Data collection and description

The following table shows the data used in this research in various formats as well as their source

Table 3.1 Summary of data and their sources

NAME	SOURCE	FORMAT	SPATIAL RESOLUTION	PURPOSE
Landsat 8 OLI imagery(2015, 2018, 2021)	Google Earth Engine	Tiff.	30m	Land cover mapping
Population density	Google Earth Engine	Tiff.	30m	Multi-criteria analysis
Elevation (SRTM DEM)	USGS	Tiff.	30m	Multi-criteria analysis
Boundary data	GADM	Shp.		Masking

3.2.1 Digital Elevation Model (DEM)

Shuttle Radar Topography Mission (SRTM) DEM data was downloaded from USGS website (www.usgs.gov) with a spatial resolution of 30m. The data shows elevation which in this research was one of the thematic layers for multi-criteria analysis. From the DEM data, slope map, elevation map and visibility map were also obtained and they were all used as thematic layers for multi-criteria analysis in order to obtain potential sites for the expansion of urban green spaces in Nyamagana district

3.2.2 Population density

Population density data of Nyamagana District was downloaded from Google Earth Engine in (Tiff.) format where it shows the population density of all wards in the district. The data was then exported from Google Earth Engine and imported in ArcGIS where it was classified into 5 classes using natural breaks as seen in fig (3.4)**.** Population density in this research was one of the thematic layers that were used to identify the potential areas for the expansion of urban green spaces in Nyamagana District.

3.2.3 Landsat 8 Operational Land Imager (OLI) imagery

Landsat 8 Operational Land Imager (OLI) imagery data for the years 2015, 2018 and 2021 was downloaded from Google Earth Engine with a spatial resolution of 30m. The acquisition dates for the satellite images were 13/4/ 2015, 17/4/ 2018 and 23/4/2021 and the data was used for supervised image classification so as to obtain land cover maps for the respective years, in order to show the increase of urbanization in Nyamagana District.

3.3 Data preparation

3.3.1 Image pre-processing

The workflow adapted for this study was based on the supervised image classification approach. Image preprocessing was done in Google Earth Engine (GEE); it involved a series of steps to prepare satellite imagery for classification. All acquired L1T images were ready to-use cloud-masked surface reflectance images using CFMASK function.

3.3.2 Atmospheric Correction

In Google Earth Engine (GEE), atmospheric correction was performed on each image to mitigate the influence of atmospheric effects and enable analysis of surface reflectance and derivation of biophysical variables. GEE offers several built-in algorithms, such as Dark Object Subtraction (DOS) and Atmospheric and Topographic Correction (ATCOR) model, which were utilized for the atmospheric correction process. These algorithms effectively removed atmospheric distortions from the images, ensuring accurate and reliable data for preparing training samples.

3.3.3 Radiometric Correction

Radiometric correction was performed on each of the Landsat 8 images in Google Earth Engine (GEE) by using the function “ee.Algorithms.Landsat.TOA()” which converts the digital number (DN) values of each image to top of the atmosphere (TOA) reflectance which is a radiometric measurement that is used in remote sensing to represent the amount of sunlight that is reflected by the Earth’s surface at the top of the atmosphere.

3.4 Supervised Image classification

Supervised classification on Landsat 8 images was performed in Google Earth Engine and it involved several steps including collection of samples, training data preparation as well as classifier training. The region of interest (ROI) was defined in Google Earth Engine by specifying the shapefile of Nyamagana District and the Landsat images for the years 2015, 2018 and 2021 were loaded for the dates 13/4/2015, 17/4/2018 and 23/4/2021 respectively. The bands that were going to be used for the classification were then specified which were bands B2, B3, B4, B5, B6 and B7 and the algorithm that was used for supervised classification was Random Forest algorithm.

3.4.1 Preparing Training Samples

Training samples were prepared for six land cover classes which are built up, vegetation, bare land, swamp, lake and crop land. A region of interest (ROI) which is Nyamagana District was defined, and within it, the collection of representative samples for each land cover class was done. These samples were carefully labeled with their corresponding class labels, ensuring a variation and representative range of spectral characteristics for each class. The collected training samples comprised of both spectral as well as spatial information and they did not only capture the variations of the area but also the patterns that were observed in the region of interest. The training samples were then used as inputs for supervised classification algorithms, permitting the algorithms to study and differentiate between the different land cover classes found in the region of interest.

3.4.2 Generating Training Dataset and Assigning Class Labels

The assigning of class labels was performed to each of the collected and trained samples for the land cover classes in the region of interest. The collected training samples were visually inspected and class labels were assigned to them basing on their land cover types where built up samples were assigned the label built up, crop land samples were assigned the label crop land, swamp samples were assigned the label swamp, lake samples were assigned the label lake, vegetation samples were assigned the label vegetation and bare land samples were assigned the label bare land. The class labels were accurately and consistently assigned to ensure that the training samples they carried, truly represented the present land cover classes. Class labels served as reference information for the supervised classification algorithm, enabling it to learn the spectral patterns associated with each land cover class and make accurate predictions for the entire study area.

3.4.3 Training the random forest Classifier

This process was carried out using the Google Earth Engine platform. The random forest classifier was trained using the collected training samples for each land cover class and it analyzed the connection between the information obtained from satellite images and the assigned labels for each class, improving its ability to make accurate decisions. For each class, 150 samples were collected and 70% of the samples were used for training while 30% of the samples were used for validation. Once the training was complete, the random forest classifier classified new data by assigning labels to individual pixels in the region of interest and this enabled the identification and mapping of the various land cover types present within the area of interest.

3.5 DEM filling

DEM filling involves identifying and filling depressions or sinks in the DEM in order to create a continuous and correct elevation surface. DEM fill was done in ArcGIS software by using fill tool from Spatial Analyst extension where the input raster was the DEM and the tool processed the DEM to create a continuous elevation surface making it suitable for further analysis.

3.6 Slope extraction

Slope extraction from Digital Elevation Model (DEM) was performed in ArcGIS using the slope tool in the Spatial Analyst extension which calculates the rate of change in elevation between neighboring cells, providing information about the steepness of the terrain. DEM data was loaded in ArcGIS software and the slope tool, the required parameters were specified and the DEM was then processed and slope values were calculated for each cell generating a slope layer in raster format representing the information about slope.

3.7 Visibility extraction

Visibility extraction was from SRTM DEM and it was performed in ArcGIS using the visibility tool in spatial analyst extension which analyzes and visualizes the visibility between locations within a geographic area by calculating the areas that are visible from specific points based on the elevation of the terrain. In the preparation of a visibility map, the observers' points were added manually in google earth where open areas that are near public access and engagement including playgrounds and plazas were selected. The visibility of these points was calculated and a visibility map was obtained.

3.8 Reclassification

In this research the factors that were reclassified were slope, visibility, population density, 2021 land cover map as well as elevation which are all thematic layers in multi-criteria analysis. It involved loading each of the raster dataset in ArcGIS and reclassify tool from Spatial Analyst was used to specify the parameters and allocate new values from the old values based on the specific criteria. The outputs were reclassified slope, reclassified population density, reclassified visibility and reclassified elevation with values from 1 to 5. This rating of factors is usually made in terms of five classes which are highly suitable, suitable, moderately suitable, poorly suitable and not suitable (FAO, 2006).

3.9 Analytical Hierarchy Process

In AHP, firstly pairwise comparison of criteria was performed and the results were put in a Table 3.2. The pairwise comparison matrix is a structured method that was employed to assess the relative significance of the factors used in the research in a systematic manner. The matrix was utilized to evaluate and rank the importance of the key factors which were population density, visibility, slope, elevation and the 2021 land cover map. This involved comparing each factor against every other factor so as to establish their relative priority in influencing the expansion of urban green spaces in Nyamagana District.

Table 3.2 Pairwise comparison matrix

	Land cover	Population density	Slope	Elevation
Land cover	1	9	3	5
Population density	0.111	1	3	5
Slope	0.333	0.333	1	3
Elevation	0.2	0.2	0.333	1
Visibility	0.143	0.143	0.2	0.333

Table 3.3 shows a standardized matrix that was obtained by dividing each element of the pairwise comparison matrix by its corresponding column sum. The standardized matrix ensures that the values in the matrix represent relative priorities without being skewed by differences in magnitude. The results were used to calculate the weights of the criteria in the hierarchy.

Table 3.3 Normalized pairwise comparison matrix

	Land cover	Slope	Visibility	Elevation	Population density
Land cover	0.5596	0.8430	0.4592	0.4412	0.3684
Slope	0.0621	0.0937	0.4592	0.4412	0.3684
Visibility	0.1863	0.1249	0.1531	0.2647	0.2632
Elevation	0.1119	0.0187	0.051	0.0882	0.1579
Population density	0.08	0.0134	0.0306	0.0294	0.0526

Table 3.4 shows a normalized matrix which was obtained by dividing each element in the standardized matrix by the sum of its respective column. The normalized matrix accurately reflects the relative priorities of the elements within a criterion, making it suitable for subsequent calculations in the AHP decision making process.

Table 3. 4 Normalized matrix

	Land cover	Slope	Visibility	Elevation	Population density	Weights	W/S	(W/S)/W
Land cover	0.4361	2.529	0.5058	0.413	0.2219	0.4361	4.158	9.5345
Slope	0.0484	0.2810	0.5058	0.413	0.2219	0.2810	1.4701	5.2317
Visibility	0.1452	0.0936	0.1686	0.2478	0.1585	0.1686	0.8137	4.8262
Elevation	0.0872	0.0562	0.0561	0.0826	0.0951	0.0826	0.2821	3.4153
Population density	0.0624	0.0462	0.0337	0.0275	0.0317	0.0317	0.1955	6.1672

Consistency Index Analysis (CI)

After obtaining the normalized matrix, consistency ratio was calculated in order to identify inconsistencies and develop the best fit weights in the complete pairwise comparison matrix. It first involved the calculation of consistency index and then dividing it by the random inconsistency index which for the case of this study was 1.12 as shown in the formula below.

$$CR = \frac{\text{CI}}{RI} \text{ ………………………………… Eqn (3.1)}$$

3.10 Weighted overlay analysis

This was performed in ArcGIS using the weighted overlay tool from spatial analyst extension and it involved using the weights that were obtained from AHP. The normalized criteria layers were selected as input layers and the assigned weights for each criterion were entered. After that, the output raster name and location was specified and the final suitability map was obtained.

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

4.1 Overview

The findings and analysis in this chapter help us understand how to reach the goals of the research. In this chapter, the overall results of the study are explained using maps and graphs and also a thorough review of the research findings is provided using maps and graphs to analyze as well as present the results in detail.

4.2 Land cover maps and graphs

The outputs of supervised classification were land cover maps bearing 6 classes which are urban, crop land, swamp, lake, vegetation as well as bare land. From these land cover outputs, change was depicted in the classes where there was an increase in the coverage of certain classes in the district while the coverage of other classes decreased. From the land cover output of 2015, crop land class was seen to dominate with a total coverage of 65.93% on the area followed by vegetation with 21.43%, urban class having a total coverage of 7.52%, bare land with 2.61%, the lake covering 1.91% and swamp was the class with the least domination of 0.58% in the area. With the amount of vegetation coverage being 21.43%, and urban coverage 7.52% the rate of urbanization was still not a threat to the green spaces and vegetation as a whole.

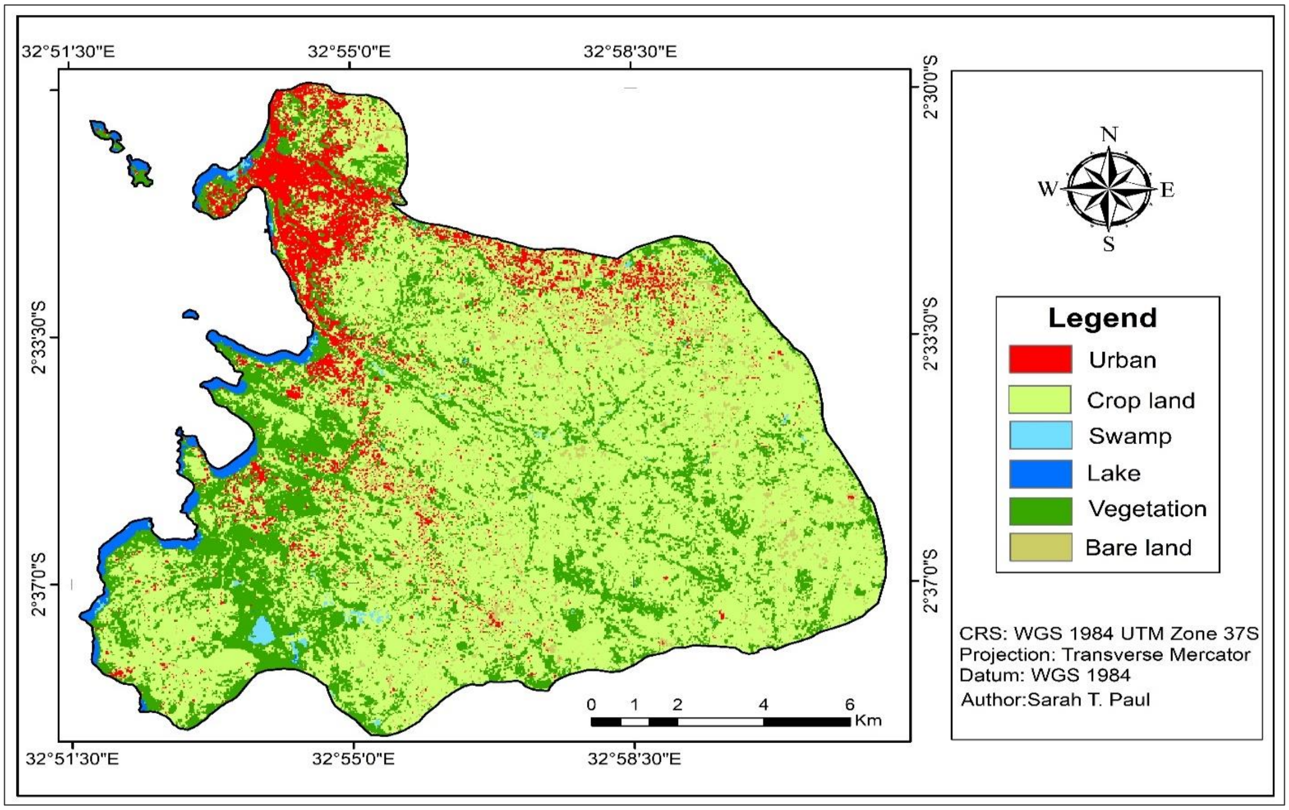

Figure 4.1 2015 land cover map

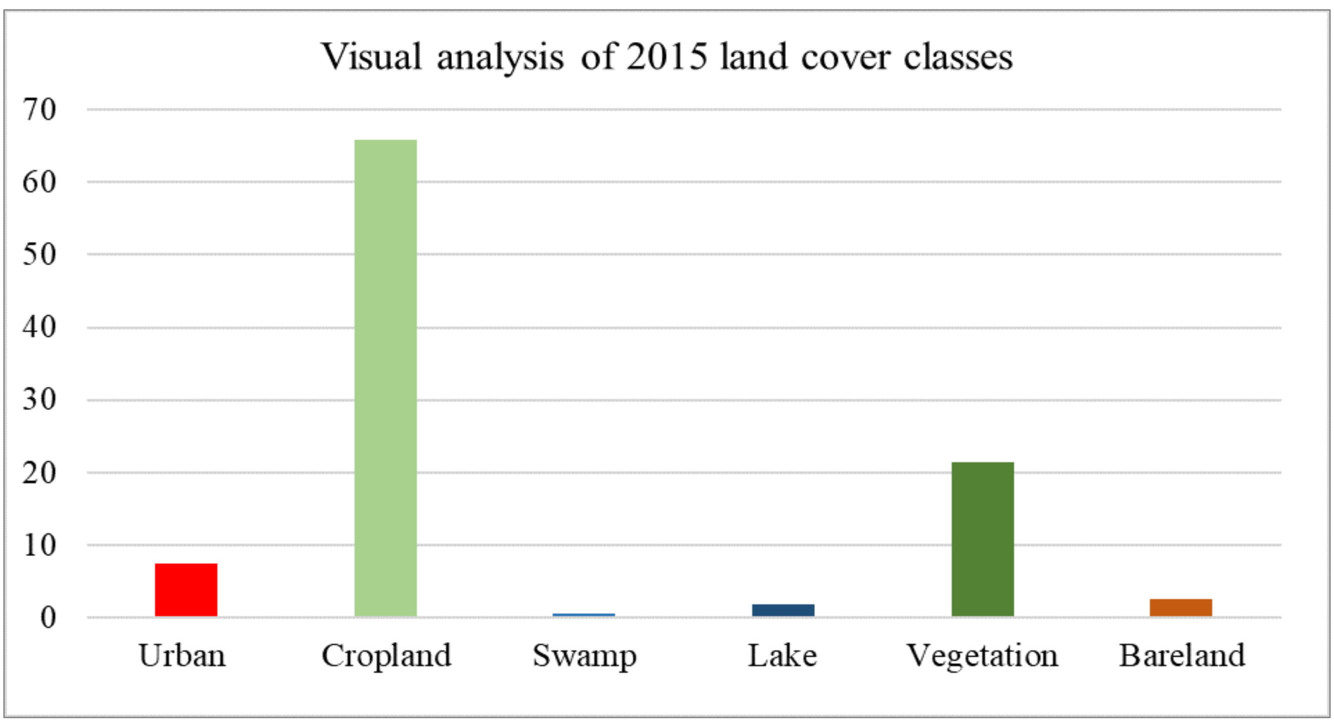

Figure 4.2 2015 land cover classes visual analysis

For the year 2018, the results of supervised classification which is a land cover map shows that the dominating land cover class which is crop land increased by 2.49% from the year 2015 with a total coverage of 68.42% in the year 2018. Urban class became the second dominating class with a coverage of 12.55% which is a difference of 5.03% from the total urban coverage of 2015. Vegetation class had a coverage of 10.25% from 21.43% in the year 2015, the amount of bare land was 6.08% which is an increase of 3.47% from 2015 bare land coverage. Both swamp and lake classes maintained their coverage of 0.58% and 1.91% respectively.

The amount of vegetation class has decreased at a high rate and the amount of urban class taking an increase at a high rate as well, can only mean that urban green spaces and vegetation as a whole is decreasing at the expense of urbanization. From the 2015 land cover map, the areas that were covered by vegetation, in 2018, are covered by urban areas and this can prove that the improvement of infrastructures and buildings is prioritized and not maintaining a sustainable and healthy environment.

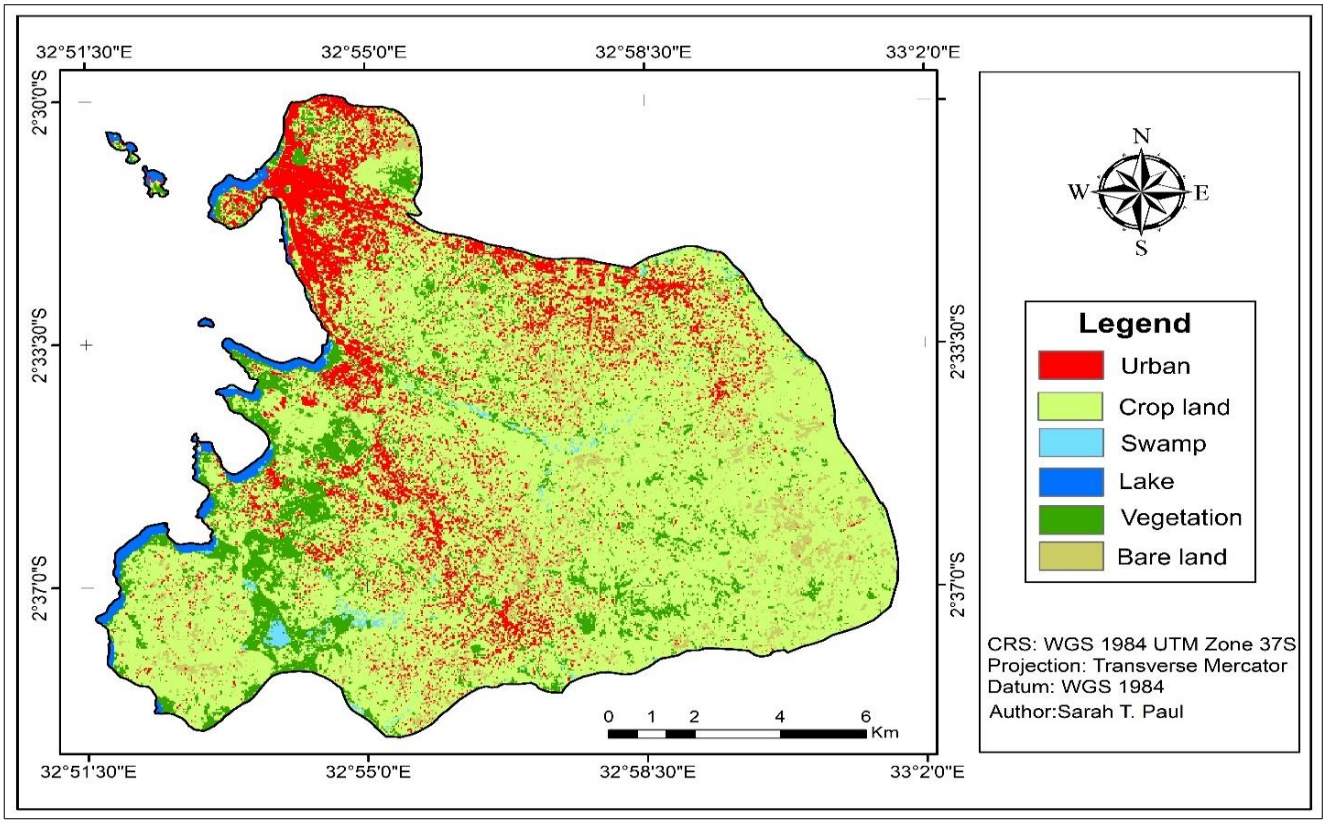

Figure 4.3 2018 land cover map

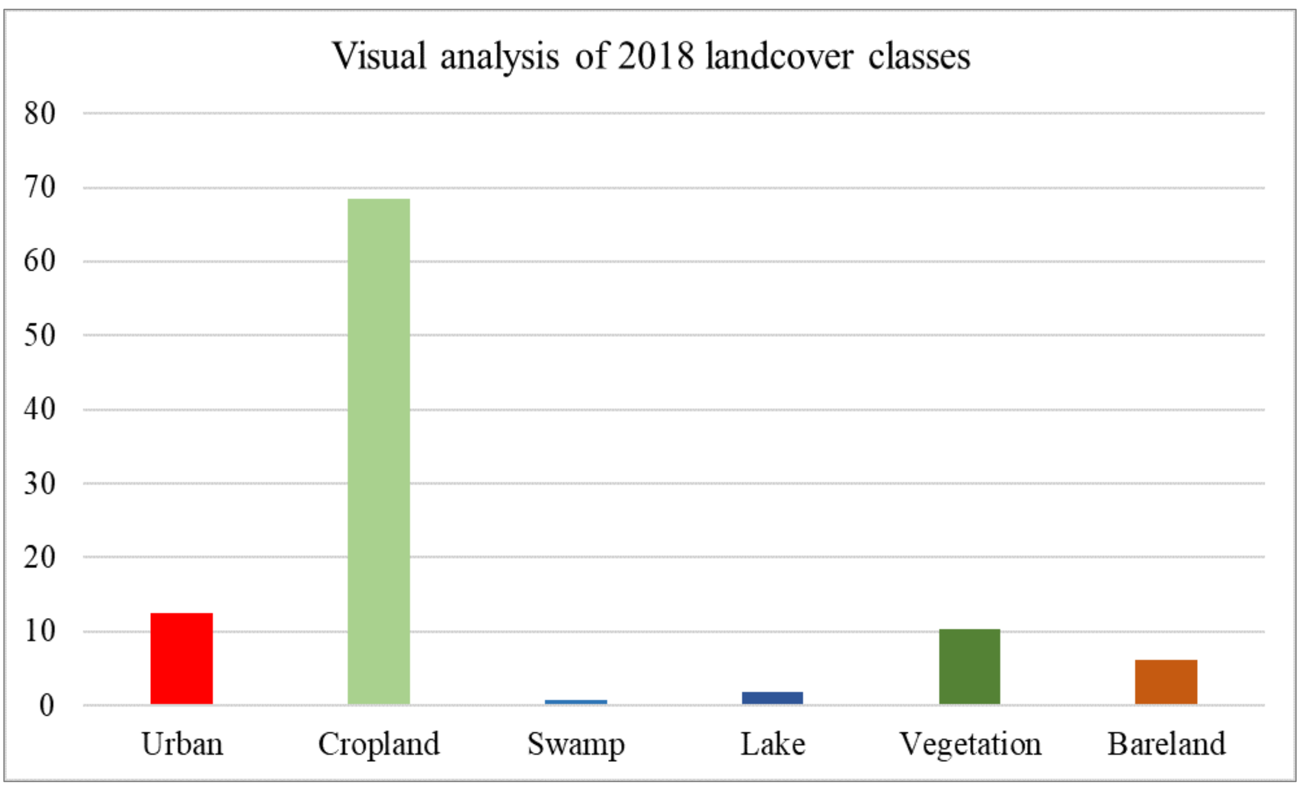

Figure 4.4 2018 land cover classes visual analysis

From the 2021 land cover map, the class that was seen to have a large coverage was the crop land class with a total percentage of 64.46% which is a decrease of 3.96% from the total coverage of crop land in the year 2018. The percentage of urban class also increased to 21.06% which is an increase of 8.51% from the year 2018 while vegetation class with a percentage of 5.98% was seen to be decreasing by 4.27% from its coverage in the year 2018. Bare land class had a coverage of 6.25% which is an increase of 0.17% from its coverage in the year 2018 while swamp class coverage having 0.36% decreased by 0.42% from the year 2018. Lake class maintained its coverage of 0.91% from the year 2018.

Vegetation class had a fall of 4.27% in the year 2021 and at the same time, urban class had a major rise of 8.51% and just as the year 2018, urbanization is increasing at the expense of urban green spaces and vegetation in the whole district. Most of the areas are now urbanized and this does not indicate any slowing down of the increase in infrastructure and buildings in the area.

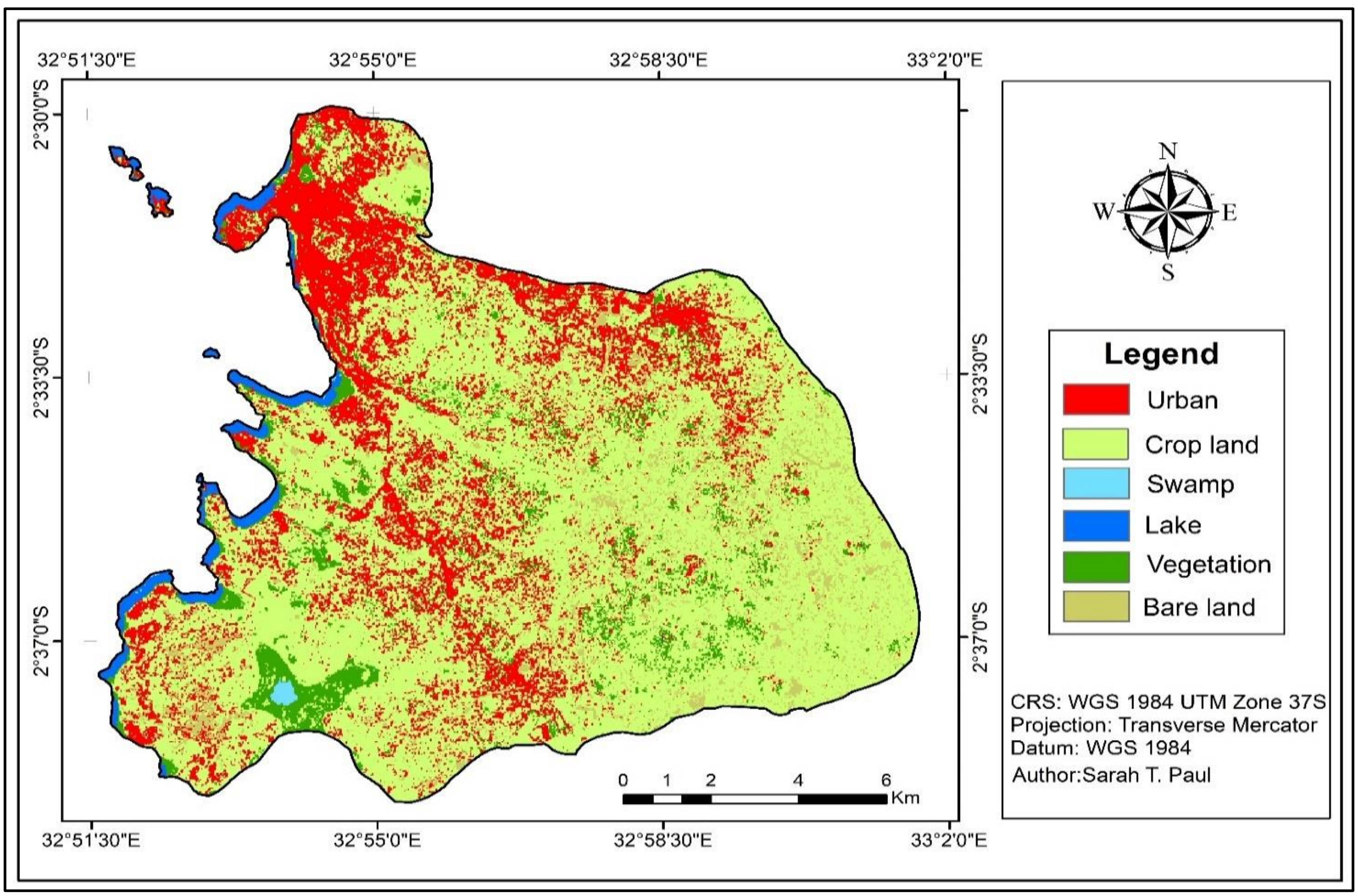

Figure 4.5 2021 land cover map

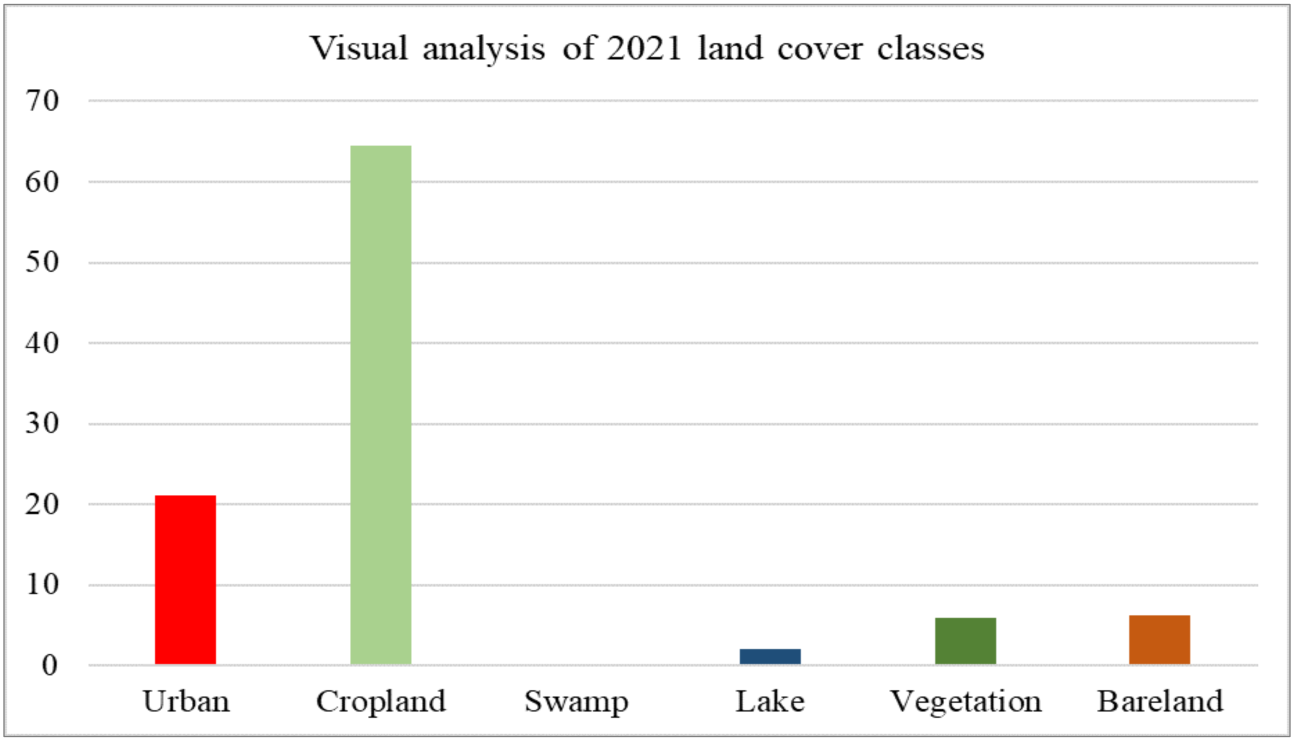

Figure 4.6 2021 land cover classes visual analysis

4.3 Reclassification maps

There were a total of 4 reclassified maps that were used in the multi-criteria analysis part of the research. These maps were reclassified population density map, reclassified slope map, reclassified elevation map and reclassified visibility map.

4.3.1 Reclassified slope map

The reclassified slope map of Nyamagana District contained 5 classes with values 1 to 5. These values were assigned to the reclassified map, basing on the old slope values of the area which were 0-3%, 4-6%,7-11%,12-17% and 18-36% that were assigned values 5, 4, 3, 2 and 1 respectively since the areas with low slope are the one that are mostly preferred for the expansion of urban green spaces.

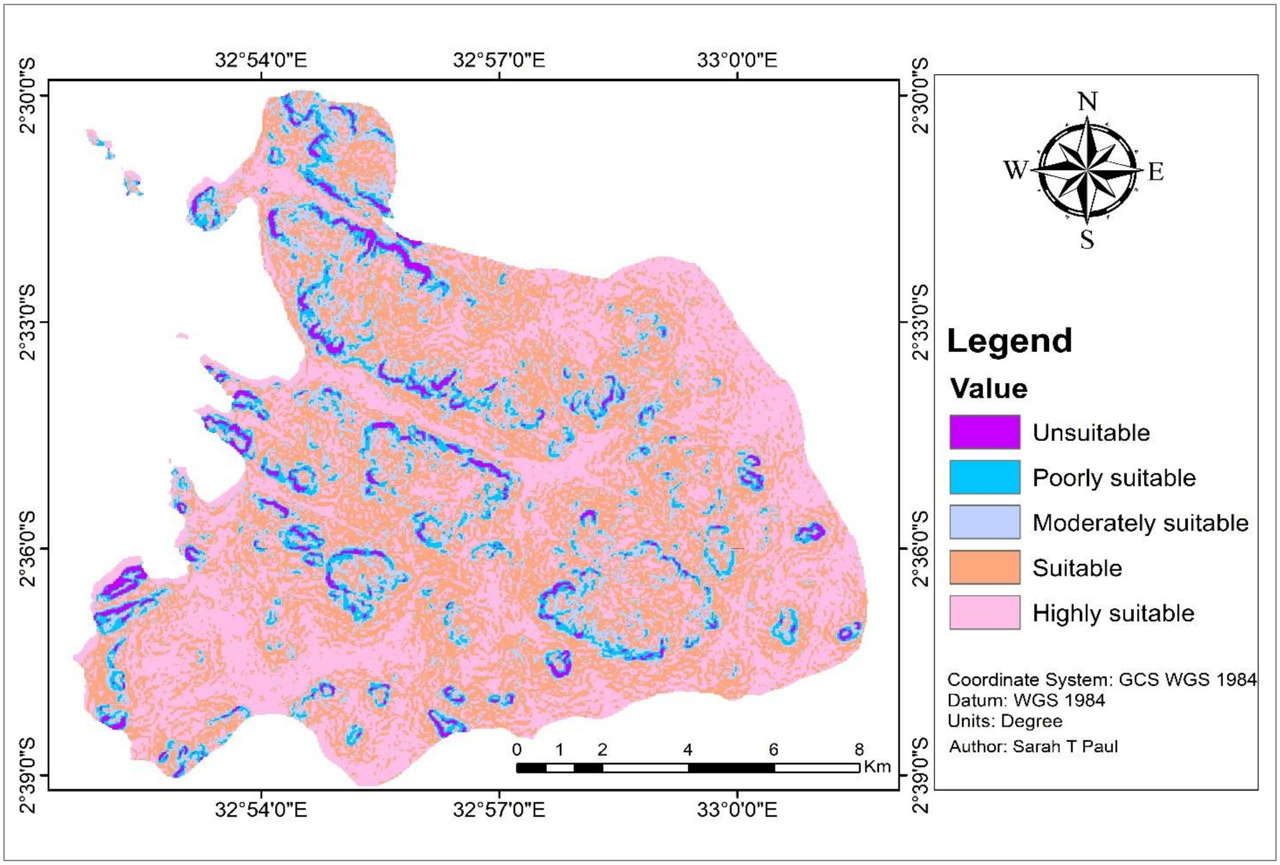

Figure 4.7 Reclassified slope map

4.3.2 Reclassified population density

Reclassified population density map had 5 classes with values 1 to 5 that were assigned depending on the old population density values which were 0-490, 491-915, 916-2319, 2320-4638 and 4639-8329 persons per square kilometer that were assigned values 1, 2, 3, 4 and 5 respectively since, as a criteria in the expansion of urban green spaces, areas with a high population density are the most preferred ones.

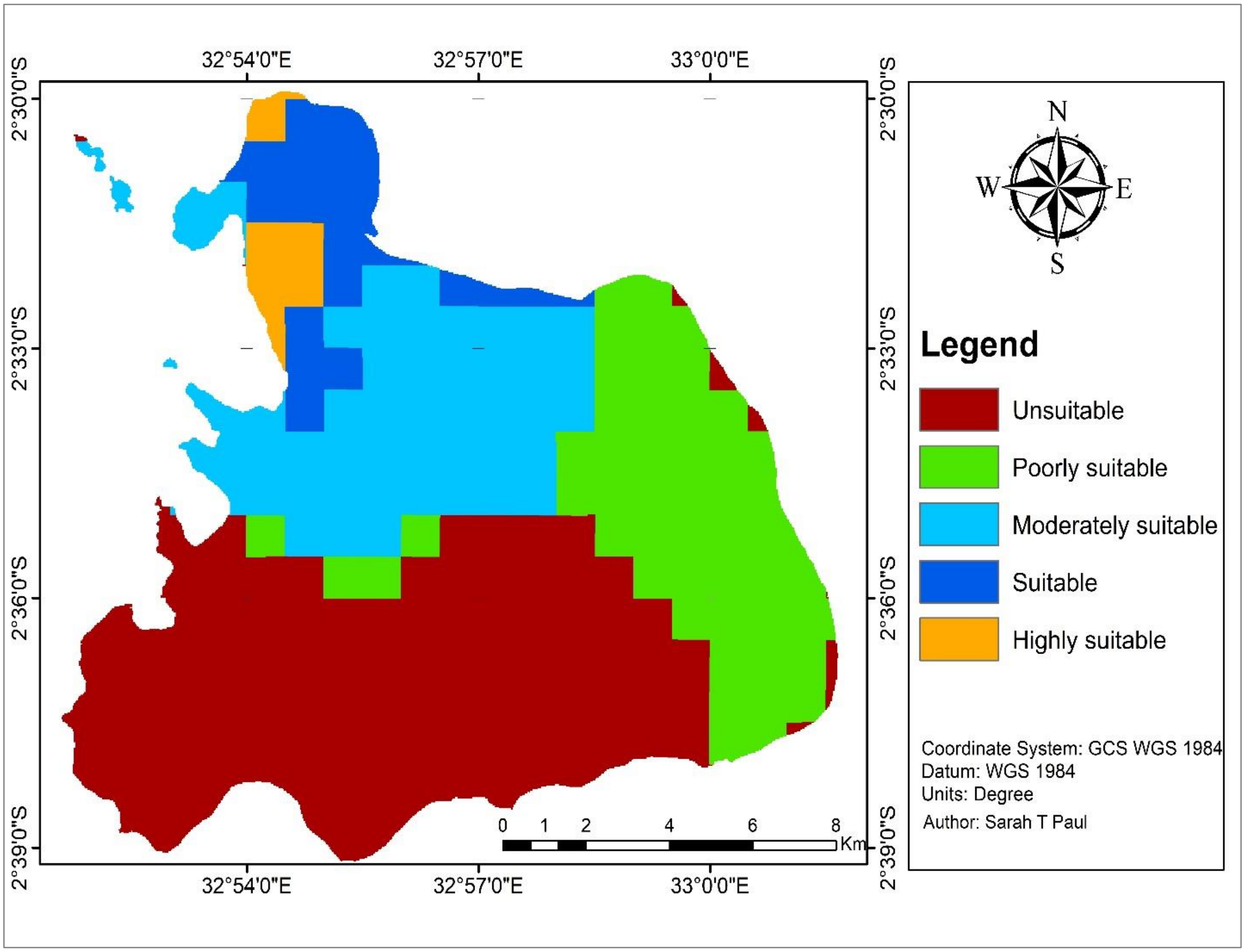

Figure 4.8 Reclassified population density

4.3.3 Reclassified elevation

The reclassified elevation map was made with five classes that were assigned values 1 to 5 from the original elevation values of Nyamagana District which were 1129-1165m, 1165-1197m, 1197-1228m, 1228-1261m and 1261-1333m that were assigned new values 5, 4, 3, 2 and 1 respectively. Areas with low elevation are the ones that are mostly preferred for the expansion of urban green spaces and therefore, low elevation was assigned the highest value which is 5 while high elevation was assigned the lowest value which is 1.

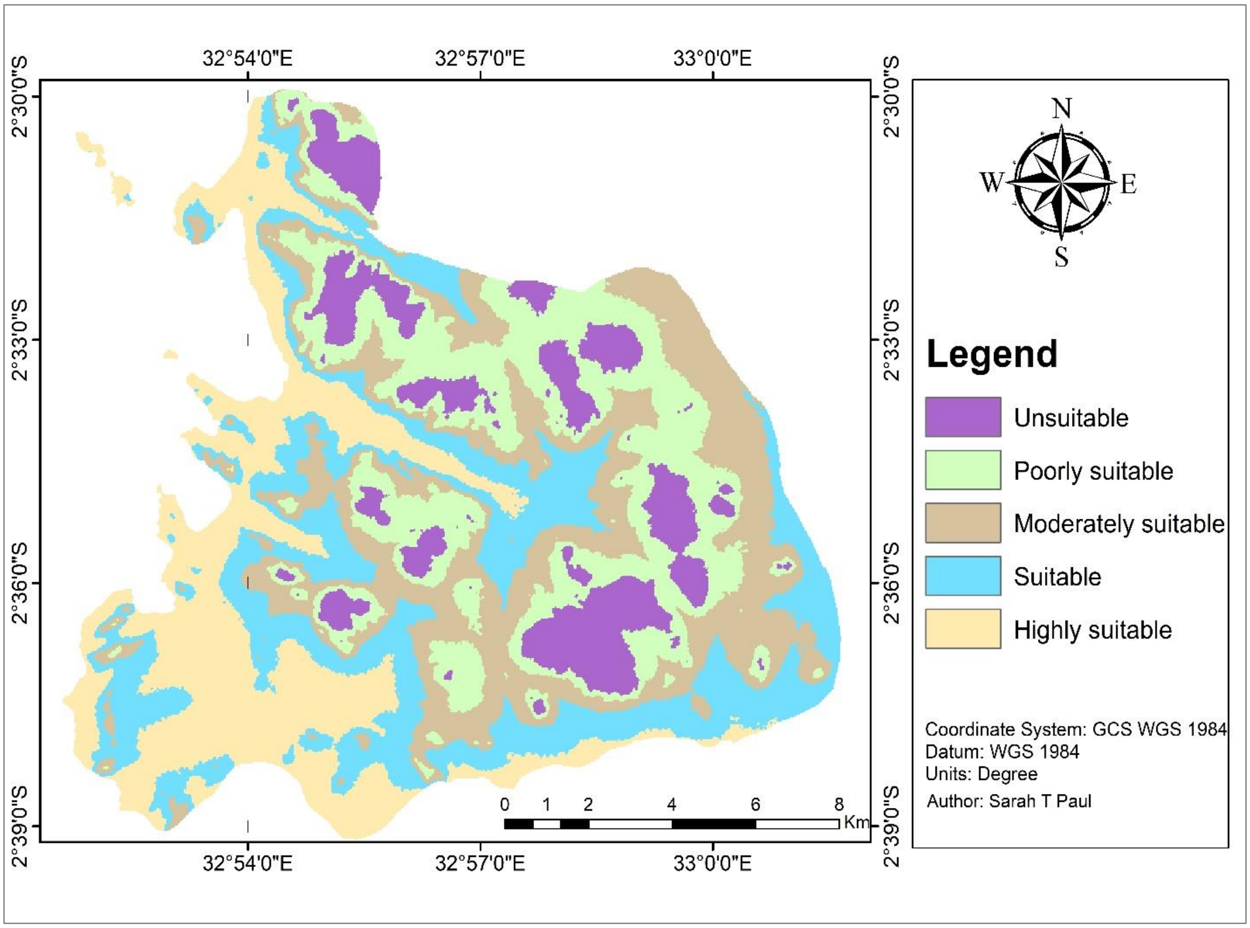

Figure 4.9 Reclassified elevation map

4.3.4 Reclassified visibility

This map was obtained after the reclassification of a visibility map that had six values which were 0, 1,2,3,4 and 5 with the areas that are most visible having a value of 5 and the ones that are not at all visible having a value of 0. These values were assigned new values during reclassification which were 1 to 5 and the most visible areas had the highest value which was 5 while the areas that were not all visible having a value of 1 because for the expansion of urban green spaces, it is important that the area selected is visible.

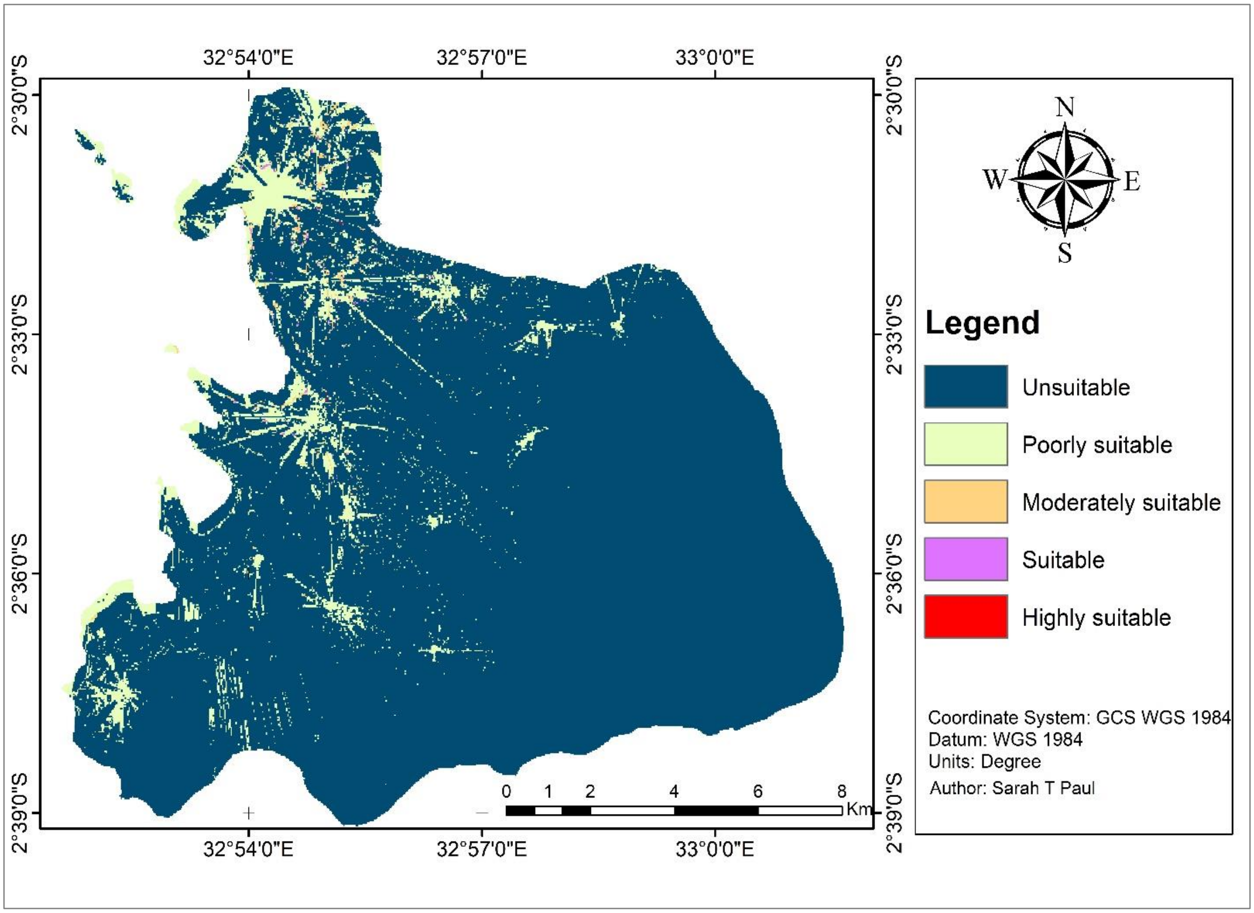

Figure 4.10 Reclassified visibility map

4.4 Final suitability map

The final suitability map that was developed from the weighted overlay analysis had a total of five classes ranging from 1 to 5, the highest class being 5 and lowest being 1. Referring to a similar study conducted by (Gelan, 2021) on urban green spaces planning using GIS-based multi-criteria analysis, highly suitable areas were given a value of 5, suitable areas were given a value of 4, moderately suitable areas a value of 4, moderately suitable areas a value of 3, poorly suitable a value of 2 and unsuitable areas a value of 1.

From the suitability map, poorly suitable areas had a percentage coverage of 57.4%, suitable areas had a coverage of 20.4%, moderately suitable areas covering a percentage of 12.6%, highly suitable areas had a percentage coverage of 6.17% and unsuitable areas having the least percentage coverage of 4.3%. This shows that with the used factors and criteria, many areas in Nyamagana District can be used for the expansion of urban green spaces and creating new ones.

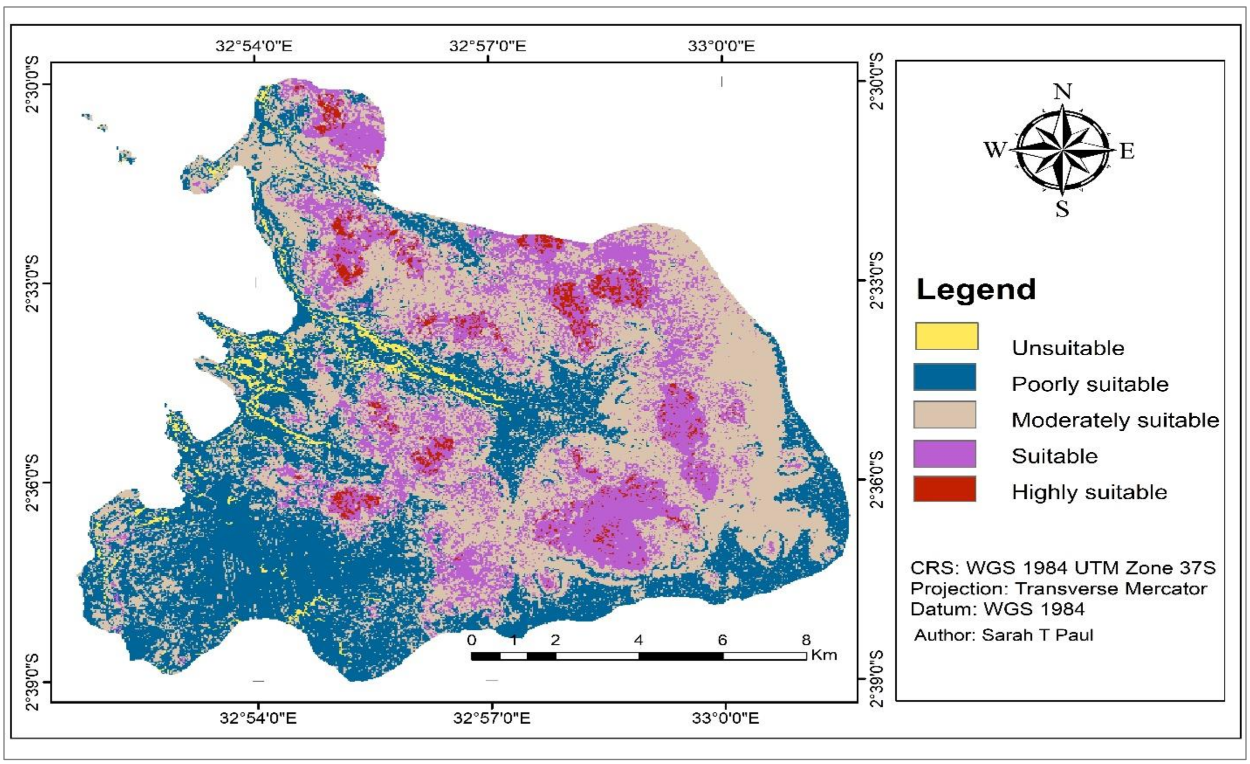

Figure 4.11 Final suitability map

4.5 Discussion of the results

The objectives of the research required quantifying the temporal evolution of urban green spaces and their relationship to urbanization, as well as the identification of their potential expansion areas. From the results obtained in land cover mapping, an increase in urban class was inversely proportional to vegetation class since vegetation was deteriorating at a high rate while urban areas were increasing at a high rate and this shows that buildings and infrastructure are increasing at the expense of urban green spaces. Also from the results of multi-criteria analysis, poorly suitable areas had a percentage coverage of 57.4%, suitable areas had a coverage of 20.4%, moderately suitable areas covering a percentage of 12.6%, highly suitable areas had a percentage coverage of 6.17% and unsuitable areas having the least percentage coverage of 4.3%. Although a large percentage coverage of Nyamagana District was poorly suitable for expansion of urban green spaces, most of the areas were fit for the expansion and creation of new urban green spaces.

Comparing this study to a study on "GIS - based multi - criteria analysis for sustainable urban green spaces planning in emerging towns of Ethiopia" (Gelan, 2021), the results did not show much of a variation since most of the areas were suitable and moderately suitable for the expansion of urban green spaces in Ethiopia. For the case of Nyamagana District, most of the areas appeared to be suitable and moderately suitable even though, poorly suitable areas occupied the largest coverage. The results have shown a variation due to the data used where in this research, a total of 5 factors were used where as for the research by (Gelan, 2021), a total of 11 factors were used which were more or less similar to this research. And also various contexts such as environment and climate of the study areas have contributed to results variation.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Overview

The chapter serves as a comprehensive summary of the findings and analysis conducted throughout the study where the key insights derived from the research are synthesized and the definitive conclusion is drawn based on the evidence presented. Furthermore, valuable recommendations based on the study's outcomes are provided and they are designed to address the challenges faced while conducting the research.

5.2 Conclusion

There are changes in patterns of urban areas in Nyamagana district as seen in the 2015, 2018 and 2021 land cover maps. The percentage coverage of urban class has been increasing from 7.52%, 12.55% and 21.06% in 2015, 2018 and 2021 respectively. As urban class coverage was increasing, vegetation coverage was decreasing rapidly where its percentage coverage was 21.43%, 10.25% and 5.98% in 2015, 2018 and 2021 respectively. This actually means that urban class which represents buildings either commercial or settlement and population, are increasing at the expense of vegetation and urban green spaces as well and this means that even the remaining urban green spaces are diminishing and at a threat of disappearing.

In the expansion of urban green spaces using the five factors which were 2021 land cover map, slope, elevation, population density and visibility, the study has shown that a few places in the district were highly suitable for the expansion of urban green spaces and the number increased for suitable and moderately suitable areas for expanding the existing urban green spaces. Most of the areas were poorly suitable and non-suitable areas had the lowest coverage for the expansion of existing urban green spaces. The poorly suitable areas and non-suitable are mostly areas with very few settlements and agricultural areas.

5.3 Recommendations

From the conclusion and findings of this research, further studies can be performed on the expansion of urban green spaces in Nyamagana district basing on other factors and criteria including the ones used in this research as well. Factors like land ownership, road networks, flood prone areas, rivers and vegetation cover can be used in determining potential areas for the expansion of urban green spaces in Nyamagana district.

Furthermore, by using ground data the research can be extended to determining the size of urban green spaces that should be expanded and also the types of urban green spaces that should be located at a particular place basing on the criteria.

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ANP) for Decision Making Decision Making involves setting priorities and the AHP / ANP is the methodology for doing.

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