MAKERERE UNIVERSITY

A GIS ASSESSMENT OF THE EFFECT OF UNCONTROLLED URBANISATION ON ECO SYSTEM SERVICES IN WAKISO, UGANDA: A CASE STUDY OF KYENGERA TOWN COUNCIL, WAKISO DISTRICT

BY

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RESEARCH REPORT SUBMITTED TO THE COLLEGE OF ENGINEERING, DESIGN, ART AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF MASTER OF SCIENCE IN GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY OF MAKERERE UNIVERSITY

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DECLARATION

I Sitenda Nicodemus Magulu, declare that this research report is my original writing and has not been submitted to any University or Institution of higher learning for any kind of award of academic qualification.

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APPROVAL

This is to certify that this dissertation has been submitted for examination with my approval as the student's supervisor.

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Supervisor: Dr. Allan Mazimwe

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Date………………………………………

DEDICATION

I dedicate this dissertation to my dear mother Nalweyiso Jacinta Kyagera and my late father, Evangelist Robert Naaman Kyagera Magulu **(RIP)** for showing me the value of education despite their levels of income.

My dear wife Nabayego Jackie Magulu for your relentless support.

All the children of peasant farmers, education is the only way to provide an equal platform for all of us to put a building block on this world.

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ABBREVIATIONS

ENVI	Environment for Visualizing Images
ES	Ecosystem Service
ESV	Ecosystem Service Value
ESV	Emergency Shutdown Value
ETM+	Enhanced Thematic Mapper Plus
EV	Electron volt
GIS	Geographical Information Systems
GPS	Global Positioning System
Ha	Hectare
HVAC	Heating, Ventilation, and Air Conditioning
ID	Identification
LC1	Local Council One (1)
LEED	Leadership in Energy and Environmental Design
LULC	Land Use and Land Cover
NIR	Near InfraRed
PCA.	Principal Component Analysis
ROI	Region of interest
SLC	Single Look Complex
UBOS	Uganda National Bureau of Standards
UN	United Nations
US	United States
USD	United States Dollar

ABSTRACT

This study investigated the trend of the LULC and variation of ESV in Kyengera Town Council using remote sensing data for twenty years, from 2000 to 2020. Also, the study clearly states the importance of remote sensing and satellite images in quantifying land cover changes and ecosystem conservation that was covered in the objectives of the study.

The study area was centred and rotated on Kyengera Town Council situated along Kampala – Masaka road and its headquarters are located at Nsangi – Mukono in Nsangi parish, approximately 15km from Kampala Capital City Authority.

The primary data included GPS coordinates picked to aid in accuracy assessment and field photos and the tools used included, Google Earth Engine, ENVI software, Arc GIS and Microsoft office for the tasks summarized; also, those tools were used to extract urbanization and vegetation cover data.

The methodology used mainly included the pre-processing methods that were done to remove flaws and deficiencies in the images due to atmospheric and electric noise and, included operations such as atmospheric and radiometric corrections, tasseled cap and PCA.

LULC change was being driven by a combination of factors, including growing urban populations and their livelihoods, unplanned urban settlement, transportation congestion, air pollution, unmanaged solid waste disposal, and global climate change.

Also, the findings of this study suggested the current value of ecosystem services; also suggested that policymakers should consider the regional heterogeneity of ES supply and the gradient analysis for a more accurate definition of ES supply.

However, the study provided the new insight into variation in ESV in the region over the past 20 years of the study period.

In summary, the study recommended the integrating nature-based solutions in urban development plans, policies, and financial support for implementing smart interventions; some of the recommended plans were green roof space, rainwater harvesting, sufficient use of clean and green energy, and plantation in available spaces at large scales with the active participation of communities and coordination with governmental bodies to enhance the ecosystem services by increasing LULC dynamics.

The results of this study were useful in land use, and land cover model analysis tests alternate approaches for the determination how they (land use, and land cover model analysis tests) affected the ecosystem. ESV calculation was a conclusive and suitable method for valuing the ecosystem in terms of money, giving the scientific foundation for directing the policies.

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Introduction

Urbanization is a cyclical process through which the nation passes as they evolve from agricultural to industrial societies (Rituraj & Priti, 2016). Urbanization can also be defined as a population shift from rural to urban areas i.e. The gradual increase in the proportion of people living in urban areas and the ways in which each society adapts to the change. (Rituraj & Priti, 2016), define urbanization as a society's transformation from a predominantly rural to a predominantly urban population. Globally, the pace of land conversion in urbanized areas is rapid with over half of the human population living in towns and cities that arise through the conversion of natural land surfaces to the built form like buildings, roads, parking lots and other sealed surfaces. (Martin, Zhiyao, Kevin, & Zoe, 2016). Urbanization usually takes place in a radial direction around a well-established city or linearly along highways.

The rising demand for urban land therefore tends to be met primarily by converting peri-urban agriculture land at the periphery of the existing built-up area (UN-Habitat, 2010, Toulmin, 2008). Urban development is characterized by physical growth which extends beyond metropolitan and city planned boundaries, into the unplanned urban fringe, and disseminates from city centers in all directions (Firman, 2009).

The unavoidable expansion of these cities takes place in areas that are not part of the already planned city boundaries, making developments to occur in unplanned way hence imposing challenges in land administration and management in these peri-urban areas. Peri-urban areas and peri-urbanization have been emerging challenges for planning cities and regions (Hudalah, et al., 2007). The expansion of cities takes place in peri-urban areas that contain a (dis)organized cluster of residential, commercial, rural-residential, and often varied agricultural uses (Mandere, Ness &Anderberg, 2010). In Africa, peri-urban zones are prospective places for disease outbreaks and other social hazards due to their general lack of planning and institutional integration (Chirisa, 2010). There are also important processes related to the environment, including agricultural decline, dispersed patterns of urban occupations, illegal settlements, disposal of solid and toxic waste, and environmental stress on green and recreational area (Aguilar, 2008; Douglas, 2006).

Due to the rapid growth and urbanization of Kyengera Town Council, uncontrolled Urbanization has greatly affected the vegetation cover on the available land a key component of ecosystem services thus resulting into growth of organic and disorganized cities. Information on how uncontrolled urbanization affects ecosystem services provision in cities is still lacking and this research will aim at that.

Rapid urbanization has currently made vulnerable the gazetted lands especially the swamps and wetland for urban development in the peri-urban areas. Hence there is an increasing occurrence of the transformation of gazetted wetland and vegetated lands to urban land at the peri-urban areas which leads to changes in the ecosystem services arising from the changes due to the pressures in the demand and supply of land from public sector, private sector and civil sector.

In addition, urban spatial expansion often depicts fairly extensive consequences on the lives of the peri-urban zone residents and on the fringing natural environment as settlements become part of the built-up urban area, thus comprising a complex mixture of permanent houses, crudely built shacks and rural huts, a transition that is more pronounced from rural to urban the closer the city comes (McGregor et al, 2006) and this affects the urbanization process in a skewed way.

The question which arises in this instance is whether urbanization which is characterized by uncontrolled urbanization can support urban development and eco-system services provision which requires urban planning.

1.2 Background

The population of people living in urban areas in all regions is increasing due to uncontrollable movement of people from rural to urban areas attributed to well-paid job opportunities, better education, health and other daily life facilities. Urban areas could include gazetted urban cities, municipalities and town councils and ungazetted trading centers. (UBOS, 2014). The transition of urban water shades from their natural, forested state to a predominantly urban condition includes the removal of vegetation, compaction of soil, alteration of natural drainage networks among others (Shende et al 2012), thus uncontrolled urbanization is one of the global phenomena occurring all around the world today. Uncontrolled urbanization is responsible for changes in the physical environment and the spatial structure of cities. In many developing countries, uncontrolled urban development is threatening the environment including the vegetation thus resulting in urban areas that are characterized by inadequate housing, urban poor, informal settlements and congestion thus leading to lack of accessibility, that may prove very costly to resolve in future (Javaid, Divya, & Krishna,2013).

Some of the planned city types include; the Grand manner, Garden cities of tomorrow, the Gothic revival and the modernist city which resulted due to evolution of urban form and institutional cities and utopian cities that resulted due to modern city planning.

Kyengera Town Council is in Central region approximately 9 Km from Kampala city in the southwestern direction. and is dominantly an urban area of Wakiso District which is urbanizing at very fast rate due to the spillover from Kampala City. Due to uncontrolled urban growth, natural features like trees, swamps, among others are replaced with the built environment like buildings, parking lots, roads, pavements among others and as such the elements that provide eco-system services are being altered with thus affecting their availability.

Various studies on urbanization concentrate on effects of urbanization on arable land, access to adequate housing, Urban Temperatures, Urban Heat Island, Land surface moisture among others ignoring the effects on eco-system services which is vital for quality of life for urbanites.

In a study conducted by (Javaid, Divya, & Krishna,2013) on effects of Urbanization on Land use change in Srinagar City, India, they found out that urbanization had caused many impacts associated with the reduction and conversion of green space for urban uses and inadequate infrastructure.

In another study conducted by (Mundhe & Jaybhaye, 2014) on impacts of urbanization on land use change in Pune, India, using geospatial techniques, they found out that urbanization resulted to unprecedented urban sprawl and loss of agricultural land. It should be noted that there are competing land-uses and there is a tendency to encroach on the fragile ecosystem which are turned to agriculture and later to build-up land.

Uncontrolled urbanization leads to improper development in any city thus cities would soon become urban slums with the least livable conditions for city dwellers in the future as vegetation cover is altered which adversely affects the provision of ecosystem services which can be achieved by cities adopting to the green growth. This calls for researching and understanding the trend of urbanization.

The major parameters to be considered in evaluating the effects of uncontrolled urbanization on eco system services will mainly be the trend of Vegetation and Bare Ground in relation to built-up environment. Shifts in vegetation cover can have a strong impact on the ecosystem function, carbon and energy balances.

However, information pertaining the temporal changes of urbanization in relation to vegetation cover a key component of eco system services is still lacking and this research will aim at using remote sensing methods, digital multi spectral images (Landsat) and remote sensing software (ENVI) to assess the effect of uncontrolled urbanization on eco-system system services considering vegetation cover as a key component of ecosystem services.

1.3 Problem Statement

Urban towns in Uganda, Kyengera Town Council inclusive are continuously expanding in the unplanned poor peri-urban communities (Makabayi&Musinguzi, 2015) which contain a (dis)organized cluster of settlements and often varied agricultural uses (Mandere, Ness &Anderberg, 2010), making developments to occur in unplanned way, and hence imposing challenges on land management in these peri-urban areas (Cohen, 2006).

Uncontrolled urbanization is one of the major environmental challenges facing the world today. One of its pressing effects is alterations in the eco system services because of changes in urban vegetation. During uncontrolled urbanization, sustainable urban development usually involves wholesale removal of vegetation. This leads to growth of poorly designed urban centers which affect provision of ecosystem services obtained from vegetation, trees, landscape strips, open spaces among others. Nevertheless, the effect of uncontrolled urbanization on ecosystem services in cities is not yet known and this research will examine that using remote sensing methods.

1.4 General Objective

To evaluate the effect of uncontrolled urbanization on provision of ecosystem services in urban areas.

1.4.1 Specific objectives

i. To determine land cover patterns from 2000 to 2020.
ii. To evaluate the relationship between changes in Vegetation cover, Bare Ground and Urbanization.

iii. To find out how uncontrolled urbanization affects urban ecosystem services.

1.5 Research questions

i. What is the land cover patterns in 2000, 2010, and 2020?
ii. What is the relationship between changes in vegetation, Bare Ground and urbanization?
iii. How uncontrolled urbanization can influence urban ecosystem services?

1.6 Scope

The study will be carried out in Kyengera Town Council, Wakiso District in Central Uganda. The study will only concentrate on effect of uncontrolled urbanization on ecosystem services in Kyengera Town Council excluding other effects of uncontrolled urbanization like Land surface temperature, Air quality, inadequate housing among others. Only vegetation cover will be considered excluding other elements of cities like pedestrian zones, legibility and way finding among others thus no emphasis will be put on other factors that affect vegetation cover like; deforestation, swamp reclamation, bush burning among others. This is because most of these other aspects that affect urban vegetation are no more in most urban areas. Both high index and low index vegetation will be considered.

1.7 Significance

Cities generate approximately 70 percent of the worldwide Carbon dioxide emissions and are the primary cause of air, water and environmental pollution and this can only be overcome through planned urbanization. These are vital in urban design and planning due to the increased rate of sustainable urban growth. Thus, the information can be used by urban planners when determining green belts since green belts can help check the uncontrolled radial and linear expansion of cities.

The information can be used to monitor urban expansion thus implement policies to optimize the use of natural resources while accommodating development at the same time minimize the impact on the environment. Information pertaining vegetation cover will be attained and this being a key component of planned cities can be used in delivering ecosystem services such as temperature mitigation, carbon uptake among others.

The research can be applied in physical planning and urban design and governmental organizations. Bodies like the Africa Smart City Forum and the Intelligent Community Forum would use the attained information in decision making in rating the quality of life in cities using the ecosystem service index in cities.

The data can also be used to map the endangered zones since the vegetation cover is changing at the expense of the built-up areas and also aid in quick and useful decisions for the purpose of administration and planning for a sustainable urban development which enhances the quality of life in urban areas.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Cities are and will continue to be important as centers for civilization, commerce, innovation, and as the home for millions of people including the poor. (Botikin & Beveridge, 1992). With the increasingly urbanized species, more than 60% of the people in the world will live in urban areas and the related suburbs by 2030. Urban areas refer to all areas covered by asphalt, concrete, typically commercial and industrial buildings with open roofs as well as open transportation facilities, airports, parking lots and multi-lane state highways, single/multiple family houses and public rental estate.

Urbanization is the physical growth of cities due to movement of people from rural areas to cities leading to growth in urban populations. Urbanization can also be defined as the movement of people from rural to urban areas due to global change. Urbanization levels are high in Less Developed Countries due to: Rural to urban migration due to lack of resources in rural areas and mentality of people in rural areas that the standard of living in urban areas is much better than in rural areas.

2.2 Urbanization Trends

Cities of the future will soon account for 90% of the world's population growth, 80% of its carbon emissions and 75% of its energy consumptions. Rapid expansion of city borders due to increased population would lead to outward expansion of cities and join with daughter cities to form mega cities thus by 2025 there will be about 30 mega cities. Convergence of two closely mega cities will lead to formation of mega regions for example Johannesburg and Pretoria in South Africa will form Jo-Toria.

There will be expansion of mega corridors joining two or more mega cities or regions. Evolution of smart cities with smart features like: Smart economy, Smart buildings, Smart mobility, Smart energy, Smart information communication and Technology, Smart planning, Smart citizen and Smart Governance. But according to UN Habitat, (2016) more than 60% of the world's population is expected to be living in urban areas by 2025. Nevertheless, Urbanization in Uganda is still low in comparison to other East African Countries like Kenya and Tanzania. In Uganda, Urbanization began when the Europeans came to Uganda and Increased with the construction of Uganda Kenya railway. (UN Habitat, 2016).

2.3. Urbanization rate in Uganda

According to Uganda Bureau of Statistics (UBOS), the percentage of Uganda's population living in urban areas increased from 15.77% in 2014 to 16.1% in 2015. For the country to achieve faster socio-economic transformation there is need to raise the level of urbanization. Uganda's urbanization rate stands at 5.43 % per annum.

Wakiso's rapid population growth of 6.12% (UBOS 2024) per annum has impacted on the population structure of the area. The growth rate is largely influenced by rural-urban migration resulting in increased demand for employment, land for housing, social services and infrastructure that have stimulated spatial urban development and industrialization.

2.4. Peri-urbanization

The word 'peri-urban' could be used to denote a place, concept or process (Narain & Nischal, 2007*). As a place,* it can refer to rural agricultural areas located between urban built-up areas in cities and predominantly rural agricultural areas.

As a concept, peri-urban could be seen as an interface between rural and urban activities and institutions where rural and urban development processes meet, mix and interact on the edge of cities. As a process, it could be thought of as the two-way flow of goods and services between rural and urban.

Peri-urbanization can be defined as the process of urbanization in peri-urban areas and in other words refers to the process through which peri-urban areas are physically and functionally incorporated into the urban system (Webster & Muller, 2004). It involves the conversion of rural agricultural lands to urban built-up properties and thereby entails changes in landownership patterns and transfer processes. Peri-urbanization also refers to the transformation of economic structures, from rural-based agricultural economy to urban-based economy (manufacturing and services) (Ibid). The process also entails the transformation of existing rural settlements into urban settlements (UNFPA, 2007).

2.5. Urban Design and Ecosystem Services

Urban design may be defined as the process of determining and shaping cities, towns and villages. Urban design addresses the large scale of groups of buildings, urban structure streets and public spaces, whole neighborhood and entire cities to make urban areas functional, attractive and sustainable. Urban design primarily deals with the design and management of public space and the way how the public space is utilized.

Ecosystem services on the other hand refer to the wide range of benefits that humans derive from natural ecosystems. These services are essential for maintaining the health of the planet and supporting human well-being. They encompass everything from the air we breathe to the water we drink, and the food we consume. Recognizing and understanding these services is crucial for sustainable development and environmental conservation.

Ecosystem services are also defined as the direct and indirect contributions of ecosystems to human well-being. They include provisioning services such as food, water, and raw materials; regulating services like climate regulation, flood control, and disease regulation; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as nutrient cycling and soil formation that underpin all other ecosystem functions. The concept underscores the significance of biodiversity and ecological processes in sustaining life and facilitating economic activities. Recognizing these services is crucial for environmental conservation and sustainable development.

2.6. Types of Ecosystem Services

2.6.1. Provisioning Services

Provisioning services are tangible resources directly obtained from ecosystems. They include:

- Food such as crops, fruits, fish, and livestock
- Freshwater for drinking, irrigation, and industrial use
- Raw materials like wood, fiber, and fuel
- Medicinal resources used in healthcare

These services form the foundation of many economic sectors and are essential for human survival.

2.6.2 Regulating Services

Regulating services involve the benefits derived from the regulation of ecosystem processes. They help maintain environmental stability and include:

- Climate regulation through carbon sequestration and temperature control
- Water regulation such as flood control and groundwater recharge
- Air quality regulation by removing pollutants
- Disease regulation by controlling pests and pathogens

These services are critical for reducing natural hazard impacts and ensuring ecosystem resilience.

2.6.3. Cultural Services

Cultural services encompass non-material benefits that ecosystems provide to humans. They include:

- Recreation and tourism opportunities
- Spiritual and religious values
- Educational and aesthetic experiences
- Heritage and cultural identity reinforcement

These services enhance human well-being by fostering cultural expression, spiritual fulfillment, and social cohesion.

2.6.4. Supporting Services

Supporting services are fundamental ecological processes that underpin all other ecosystem services. They include:

- Soil formation essential for plant growth
- Photosynthesis, which produces oxygen and organic matter
- Nutrient cycling to maintain soil fertility
- Habitat provision for diverse species

Understanding these categories helps in assessing the importance of ecosystems and implementing policies for their conservation and sustainable use. Protecting ecosystem services is vital for ensuring environmental stability and human prosperity in the long term.

2.7 Urban Design and ecosystem services

Urban design and ecosystem services are closely linked. Urban design refers to the process of creating and shaping the physical environment of cities and towns, while ecosystem services refer to the benefits that humans derive from natural ecosystems. Urban design plays a crucial role in shaping functioning ecosystems within city environments, directly influencing ecosystem services that benefit urban populations. Ecosystem services refer to the benefits that humans derive from natural ecosystems, including air and water purification, climate regulation, flood control, and recreational opportunities. Integrating these services into urban planning enhances sustainability and quality of life for residents.

Urban design can impact ecosystem services in various ways, such as: Green infrastructure: Incorporating green spaces, parks, and green roofs into urban design can help to maintain ecosystem services like air and water purification, carbon sequestration, and habitat creation.

Stormwater management: Urban design can incorporate features like rain gardens, permeable pavements, and green infrastructure to manage stormwater runoff, reducing the burden on drainage systems and preventing combined sewer overflows.

Urban heat island mitigation: Urban design can incorporate features like green spaces, cool pavements, and green roofs to reduce the urban heat island effect, improving air quality and human comfort.

Biodiversity conservation: Urban design can incorporate features like habitat corridors, green spaces, and wildlife-friendly buildings to conserve biodiversity and support ecosystem services.

Transportation and mobility: Urban design can prioritize pedestrian-friendly, bikeable, and public transportation-oriented design, reducing reliance on personal vehicles and supporting more sustainable transportation options.

Some examples of urban design that incorporate ecosystem services include: Green infrastructure in cities like Seattle, Washington, and Portland, Oregon

The High Line in New York City, which transformed an elevated rail line into a green space; the Cheonggyecheon restoration project in Seoul, South Korea, which transformed a former highway into a green corridor.

The Barcelona Superblock program, which prioritizes pedestrian-friendly and bikeable spaces; the Vancouver Greenest City Action Plan, which aims to incorporate green infrastructure and ecosystem services into urban design.

These examples demonstrate how urban design can support ecosystem services, creating more sustainable, resilient, and livable cities.

2.8 Strategies for Eco Urbanization

Eco Urbanization begins with strategic planning principles. Smart growth as a result of proper planning since it preserves natural environment and recognizes connection between development and quality of life. Improvement of transport networks for example ensure congestion is reduced during travel hours by planning alternative routes. Decentralized growth in that congestion is eliminated from the Central Business Districts. Public assets like open spaces, cultural sites since these can be protected compared to individual assets.

2.9. Vegetation and its importance

Vegetation includes all plants from evergreen forests to grassy meadows and crop land and vegetation covers 20% of our planet. In places where vegetation index is high, it is usually represented with dark green whereas low vegetation index is represented in Kyengera Town Council. The term vegetation is broader than flora which refers to species composition. Vegetation is classified as: Natural vegetation which refers to plant life that grows naturally and is controlled by climatic conditions of that region. Cultural vegetation which is planted and maintained by humans with considerable input of energy. Semi-natural vegetation which is included in natural landscape as humans have influenced the natural vegetation in many areas.

Vegetation is important because it acts as wind path against the Urban Island. (Kiichiro, 2010) Vegetation acts as Carbon sinks especially in urban areas thus reducing the rate of Global warming. Vegetation is a key component in urban areas and helps in temperature mitigation, pollution removal and provision of amenity values for human and habitat biodiversity. (Martin, Zhiyao,Kevin, & Zoe, 2016) Vegetation acts as an urban conservation corridor and therefore the green spaces can be used for recreation especially in urban areas.

2.10. The Dimensions of an Eco- City

An eco-city, also known as a sustainable city or green city, is an urban area designed to minimize its impact on the environment and maximize the quality of life for its citizens. Some key features that make a city an eco-city include:

Renewable Energy: Eco-cities rely on renewable energy sources like solar, wind, and hydro power to reduce dependence on fossil fuels and lower carbon emissions.

Green Spaces: Eco-cities prioritize green spaces, parks, and gardens to maintain biodiversity, absorb carbon dioxide, and provide recreational areas for citizens.

Sustainable Transportation: Eco-cities promote eco-friendly transportation options like electric or hybrid vehicles, public transportation, walking, and cycling.

Energy-Efficient Buildings: Eco-cities feature buildings designed with energy-efficient materials, insulation, and systems to reduce energy consumption.

Water Management: Eco-cities implement efficient water management systems to conserve water, harvest rainwater, and treat wastewater.

Waste Reduction and Recycling: Eco-cities aim to minimize waste and maximize recycling, composting, and proper disposal of waste.

Innovative Urban Planning: Eco-cities are designed with a focus on compact, walkable neighborhoods, mixed-use development, and accessible public spaces.

Green Infrastructure: Eco-cities incorporate green roofs, green walls, and urban agriculture to improve air quality and mitigate the urban heat island effect.

Citizen Engagement: Eco-cities encourage citizen participation in sustainability efforts through education, community programs, and public awareness campaigns.

Continuous Monitoring and Improvement: Eco-cities regularly assess and improve their sustainability performance, using data and indicators to track progress.

By incorporating these features, eco-cities aim to create a healthier, more livable, and environmentally conscious urban environment for their citizens.

5 Key Components of Green Cities

Sustainable transportation

An important part of any city is the way people move through it. Transportation should be accessible, affordable, and for green cities, it reduces reliance on cars — a leading cause of carbon emissions. A few ways that green cities make transportation sustainable are reliable bus and train systems, walk- and bike-friendly neighborhoods (designated bike lanes, wider sidewalks, more bike racks), and plenty of EV charging stations to encourage the use of electric cars.

Clean energy

Green cities also reduce environmental impact through clean energy, mainly solar power via solar farms. The benefits of solar power are far and wide; it protects homeowners from rising utility rates, reduces dependence on electricity grids, boosts the economy by creating new jobs, and significantly reduces greenhouse gas emissions. U.S. solar power offsets over 100 million metric tons of carbon dioxide annually. When solar farms are city-funded like they are in green cities, residents and municipalities can more easily go solar.

Urban farming

Urban farming produces food on small farms within cities, instead of being brought in from outside sources. Urban farming helps green cities reduce carbon emissions from food production and agriculture, while giving residents more affordable, nutritious options. These farms even enhance local soil and improve air quality. Urban farming includes various food production methods from vertical farms to community gardens.

Water conservation

An important consideration for any green city is efficient water use, to conserve as much of this precious resource as possible. Rainwater harvesting, water-savings incentives, and smart irrigation systems are all ways that these cities save water. Using data-enabled smart irrigation controllers allows cities to cut down on water costs and consumption that stems from leaks and overwatering. With droughts and water shortages on the rise, it's more important than ever that cities strive for net zero water usage.

A green city paving the way in smart water management is the Sustainable City in Dubai. In addition to using highly efficient, low-flow water features in residences, they treat all wastewater on-site and use it to irrigate their landscape. They've had smart irrigation technology and soil moisture sensors installed city-wide to conserve water and maintain plant health.

Public green spaces and green infrastructure

Public green spaces can be anything from parks to living walls to green roofs to community gardens. These spaces are multi-functional. They reduce carbon and pollution in the atmosphere, increase residents' physical and mental health, provide community spaces, and mitigate risks from severe weather events like flooding.

Historically, urban planners didn't consider natural processes, building cities as concrete jungles that are vulnerable to climate change. Green infrastructure considers the natural environment when planning urban land use. Green buildings often use solar panels, smart HVAC systems, and are LEED certified. Not only does having a city full of green buildings help keep pollutants and toxins at bay, but this infrastructure also tends to be cheaper than standard "grey" infrastructure.

Overall, green cities are more self-sufficient than average cities, making them resilient against climate change-related weather emergencies. They conserve water, save energy, and reduce carbon emissions, all while serving as beautiful, affordable, and healthy spaces for people to live.

The figure below describes the dimensions and components of an eco-city.

2. Selected elements of sustainable city

CHAPTER THREE
METHODOLOGY

3.1 Introduction

This chapter discusses all the procedures and methods used in achieving the research objectives thus provides a basis for answering the questions posed by the research. It also provides data used for the study. The procedures are summarized in the figure below.

Methodology

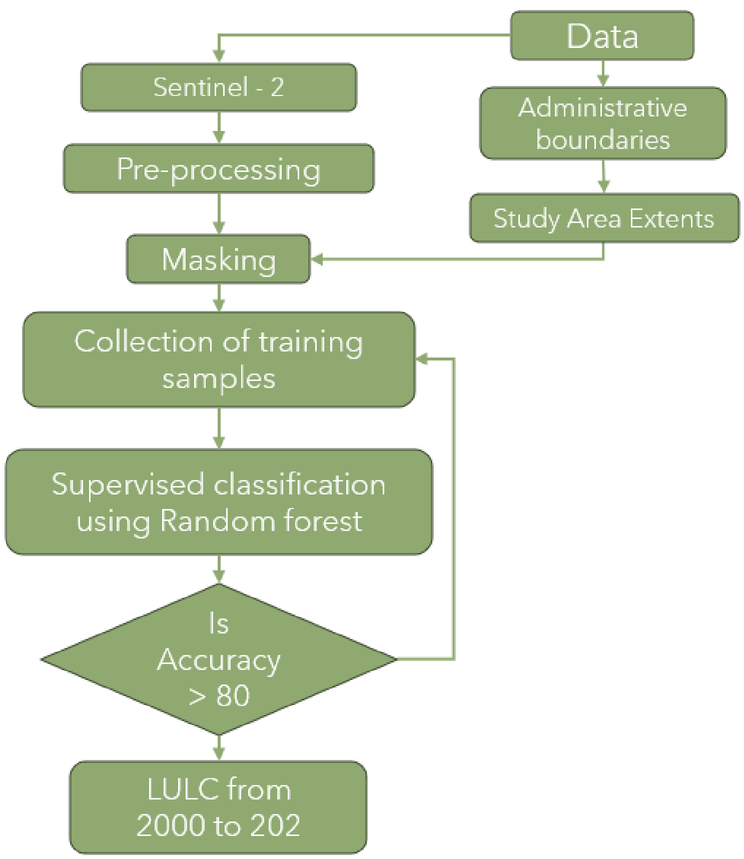


Figure 3. 1: Methodology

3.2 Study Area

Kyengera Town Council is situated along Kampala – Masaka road. The headquarters are located at Nsangi – Mukono in Nsangi parish, approximately 15km from Kampala Capital City Authority. Kyengera Town Council borders with the sub-counties of Wakiso in the north, Ssisa in the south, Makindye in the East and Kiringente of Mpigi District in the west. It is one of the component Town Councils of Busiro County. Kyengera Town Council is made up of ten wards, which are in totality subdivided into fifty four local administrative units. (LC I). The soils in Kyengera Town Council are heavily weathered lacustrine soils that due to extensive and continuous cropping have been heavily degraded and highly leached. The absence of reasonable sizes to support natural reclamation through fallowing implies seasonal fertilization to enhance feasible crop yields. Out of the total land area of 11,200 hectares, 3685 hectares is arable land of which 690 hectares is cultivated land, 1,094 hectares covered by forest, while the remaining part is in form of wetlands.(Kyengera Town Council 5-year Development Plan 2015 -2020).

Climate

The climate of Kyengera Town Council is pre-dominantly tropical wet and dry and is characterized by seasonal variations of temperature humidity and wind throughout the year. The major dry season runs from December to February while the first rains start in March and end in June. The humidity is usually high in the cropping season ranging between 70 – 85%. This is attributed to the proximity of the sub-county to Lake Victoria. Annual rainfall is about 1700mm occurring in two peaks a year. (Kyengera Town Council 5-year Development Plan 2015 -2020).

Water resources

Kyengera Town Council can be generally said to have adequate surface water reserves, although in some parts of the Town Council especially during the dry season, severe water shortage is occasionally experienced. However, this may be explained in terms of inadequate resources exploitation rather than resource scarcity.

The majority of the water resources are in form of wetlands and springs. The wetlands in Town Council include, Nammaya, Nabazizza, Mpiringisa and Mayanja, the most extensive of all. Some of the spring water sources are being conserved and sustainability utilized. About 40% of the spring water resources are protected while the majority is misused, abused and prone to health hazards.

Many areas have a shortage of water and this implies that residents have to move long distances to find household utility resources. Worst hit areas include Busembe, Mukono, Bandwe, Naggalabi and Kabojja. However, although the water yields are satisfactory, they are not especially high and sustainability is not assured. Often the protected springs and shallow wells dry up before their estimated life time and spells out clearly some degree of uncertainty in water supply from the mentioned water sources. (Kyengera Town Council 5-year Development Plan 2015 -2020)

Vegetation

The natural vegetation is predominantly tall grass and the trees scattered on farmlands plus home gardens. The major grasses include; Pennisetum, purpureum, panicum maximum, brachiaria, brizantha, setaria anceps, hyperrhenia rufa and cymbopogon afionardus. The location of Kyengera Town Council in the Lake Victoria crescent encourages growth of a vast variety of trees. Woody varieties include maezopsis eminii (musizi), markhamia lutea (musambya), sapium ellíptioum (musasa) chlorophora exelsa, eucalyptus camadulensis (kalitunsi), ficus natalensis (mutuba) and canarium schweifurthii (muwafu). (Kyengera Town Council 5 -year Development Plan 2015 -2020)

Forest Coverage

The major forest reserves include Kasenso forest reserve in Maya (1.68km2), Kajjansi Forest Reserve in Kikajjo (9km2), and Butakya Forest in Katereke (0.25km2). There are also several smaller culturally preserved forests in Nsangi. These include Kisozi, Nsangi – Mukono, Katereke and Bujaasi. (Kyengera Town Council 5- year Development Plan 2015 -2020)

The figure below shows the location of the study area.

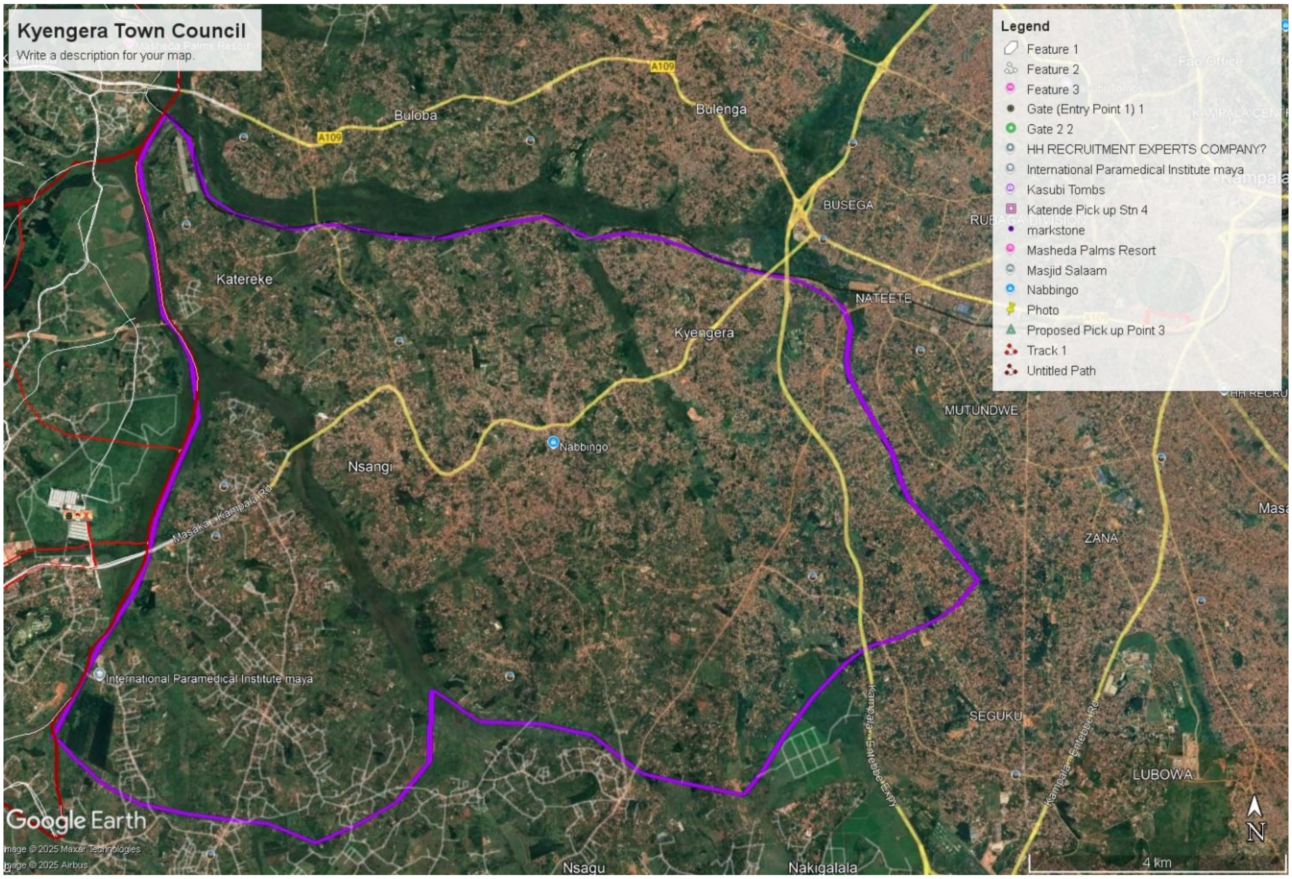


Figure 3. 2: Google earth of the study area

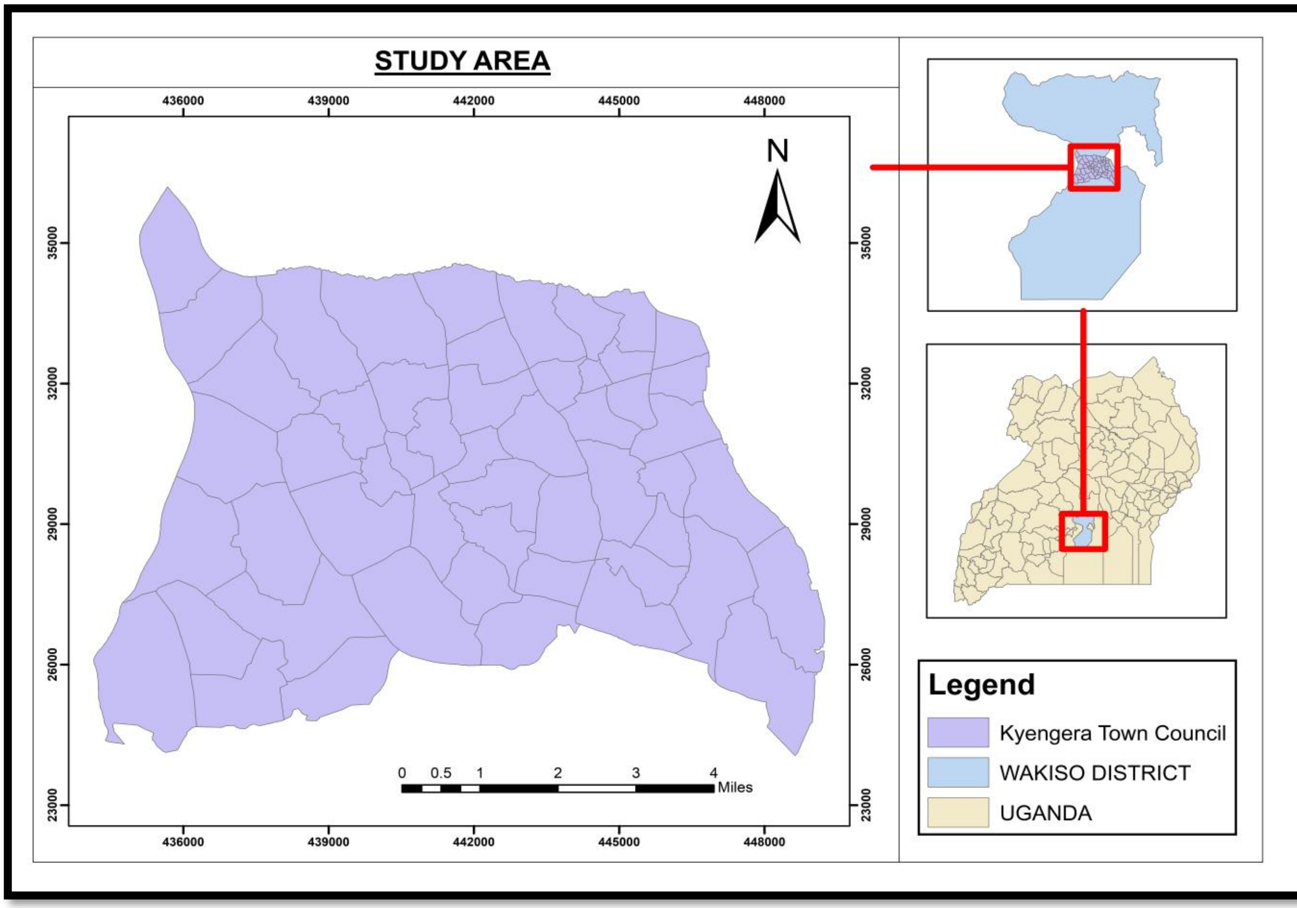


Figure 3. 3: Location of Kyengera Town Council

3.3 Data Sets and Software

3.3.1 Secondary Data.

This was mainly satellite data comprising of geo-referenced multi temporal satellite images of Kyengera Town Council captured by Landsat sensors for different years (2000, 2010 and 2020). This was because Landsat sensor covers a bigger area and the images are available at no cost and finer spectral bands. All sensors had spatial resolution of 30m and their characteristics are as shown in the table below. All images were accessed on path 173 and row 059 and acquired in November and December so as to reduce the difference among the images caused by seasonal changes.

Table 3. 1: Characteristics of the datasets used

Spacecraft ID	Bands	Band description	Acquisition Date
Landsat 5	4, 3, 2, 1	NIR, R, G, B	09/11/1990
Landsat 7	4, 3, 2, 1	NIR, R, G, B	19/12/2000
Landsat 7	4, 3, 2, 1	NIR, R, G, B	04/12/2010
Landsat 8	5,4, 3, 2	NIR, R, G, B	28/12/2023

3.3.2 Primary Data

This mainly included GPS coordinates picked to aid in accuracy assessment and field photos.

3.3.3 Software

The tools used included: ENVI software, Arc GIS and Microsoft office for the tasks summarized below.

Table 3. 2: ***Software used***

Software	Purpose
ENVI 5.2	Image processing
Arc GIS 10.0	Map making
Microsoft Office	Computations, Analysis and Report writing
Google Earth Engine	Image Processing

The tools were used to extract urbanization and vegetation cover data. Areas computed from pixel count were used for analysis of the relationships, patterns and the trends in multi-temporal images and Arc GIS in analysis of images with the structure plan of the town council. Accuracy was assessed using a confusion matrix as appended.

3.4 Details of the Land Cover types

The land cover types considered in the study area are built up, Vegetation, Bare ground, Water and others and they are fully described in the table below.

Table 3. 3: Description of the different land covers

Land Cover Type	Description
Built up	All commercial, residential, industrial areas, settlements, parking lots, roads and other sealed environment.
Sparse Vegetation	Grasslands, Crop Lands, Play Grounds, Farm Lands, Recreational areas.
Thick Vegetation	Swamps, Trees, Shrubs, plantations, herbaceous vegetation.
Bare Ground	Cultivated areas, Construction sites, Open space and Exposed soils, beaches, Exposed sands
Water	Rivers, Ponds, Lakes, Reservoirs, lagoons.
Others	Solid waste landfills, Bare rocks

3.5 Remote Sensing Method

This mainly included the pre-processing methods that are done to remove flaws and deficiencies in the images due to atmospheric and electric noise. It included operations such as atmospheric and radiometric corrections, tasseled cap and PCA.

3.5.1 Gap filling

The ETM+ images (2000 and 2010) were affected by SLC failure that occurred after 31 May 2003 thus the images had zigzag patterns along the satellite ground track. This caused a need for gap fill so as to correct the data to make it useful for analysis and it was achieved in ENVI using the Landsat gap fill tool.

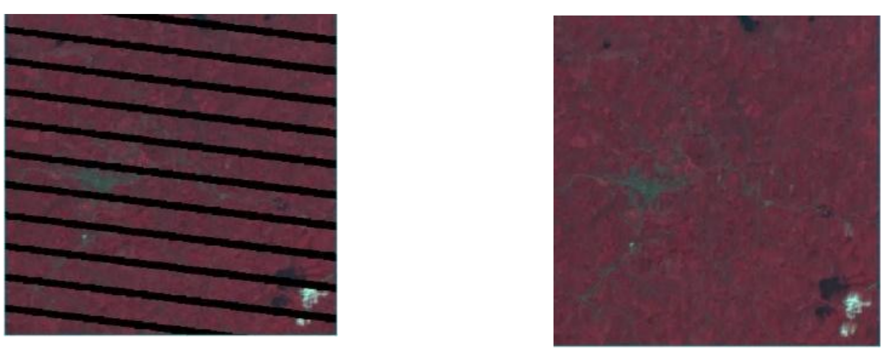


Figure 3. 4: False color composite of stripped and gap filled image of 200

3.5.2 Subsetting

This was done so that the part of the image corresponding with the study area could be the only one being worked with to avoid data redundancy. This was done using the shape file of the area imported from Arc Map as region of interest thus subsets were created via regions of interest.

3.5.3 Region of Interest

Regions of interest were created for the different land cover classes so as to act as training samples to be used for supervised classification. A minimum of 300 pixels were created for each land cover class and Regions of Interest were created in ENVI software

3.5.4 Classification

Supervised image classification using the maximum likelihood classifier was executed using ENVI software. The land use land cover classes deduced in the classification scheme were the basis of this classification. Supervised classification can be used to cluster pixels in a dataset into classes corresponding to user defined training classes. This classification type required pre- selected training areas for use as the basis for classification. Various comparison methods were then used to determine if a specific pixel qualified as a class member. ENVI Classic provides a broad range of different classification methods, including Parallelepiped, Minimum Distance, Maximum Likelihood, Spectral Angle Mapper, Binary Encoding, and Neural Net. Selecting of training areas, also known as regions of interest (ROIs) was used based on ground truth data coordinates using GPS. It is important to remember that the supervised classification in every year is independent of the classification of the other years because this method can lead to substantial overestimates of land change in the post-classification change analysis.

3.5.6 Accuracy Assessment

Due to several sorts of errors in Land cover maps that arise from classification techniques to methods of satellite data capture, a confusion matrix was used to assess the accuracy of classification so as to show the correspondence between class labels allocated to a pixel and the true class as directly observed in the field. This required collection of some field data for ground truth for the 2023 image and for back years two ROI were created and divided into two one part being used for training and another part used for ground truthing. Ground truthing was achieved using the Confusion matrix tool in ENVI.

3.5.7 Masking

This was done in ENVI using the polygon of the study area. This was to ensure that the computations of quantities were only within the study area.

3.6 Specific Objective One

Land cover maps were obtained from Arc GIS prior to the masked image from ENVI. Also Areas in hectares of the Land Cover classes were determined from the equation

Area (Ha) = [Pixel count * Spatial resolution]/10000 …….. Equation 3.1

Where pixel count was obtained from ENVI statistics and spatial resolution is 30*30 for Landsat

5, Landsat 7 and Landsat 8 respectively. Areas were computed in MS Excel.

3.7 Specific Objective Two

The built up and vegetation extent was subject to change and as such using areas pre-determined from specific objective one above, rates of change for the test years were determined. The sparse vegetation and thick vegetation were combined to form one land cover class (Vegetation) from the equation below;

Area of X=Area of X1+Area of X2……………………… Equation 3.2

Where X1 and X2 represent Sparse Vegetation and thick Vegetation respectively for a particular year of concern.

Change A =Area of A_2-Area of A_1 …………………………………. Equation 3.3

Where A_2 and A1 represent the Land cover class in the final and initial years of interest respectively. Changes were determined for all the test years that is 2000,2010,and 2020.

3.8 Specific Objective Three

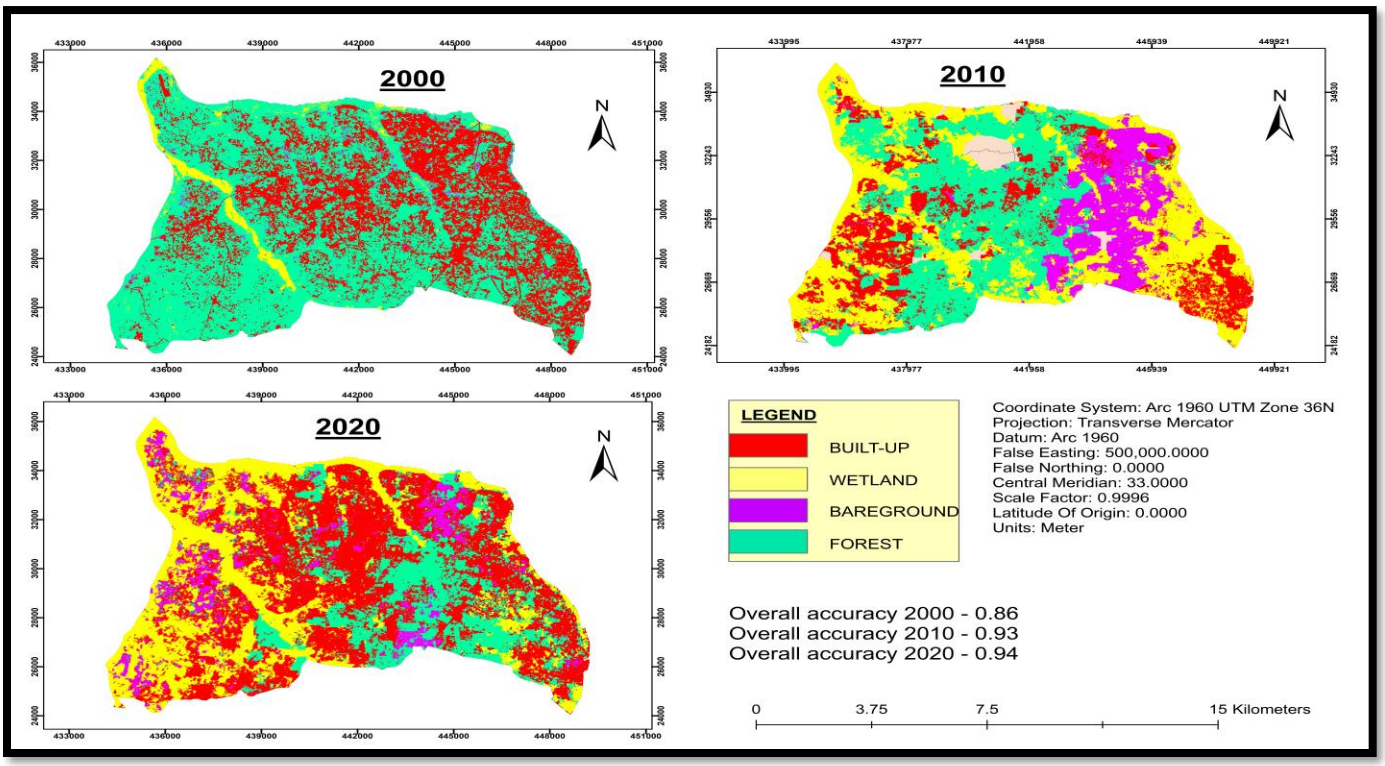
From the classified images, change detection matrices for the different pairs of years were generated using the Change detection tool in ENVI. This helped to show the transition of the land cover to built-up over the years. Thematic change maps were also generated to show the spatial distribution of the changes.

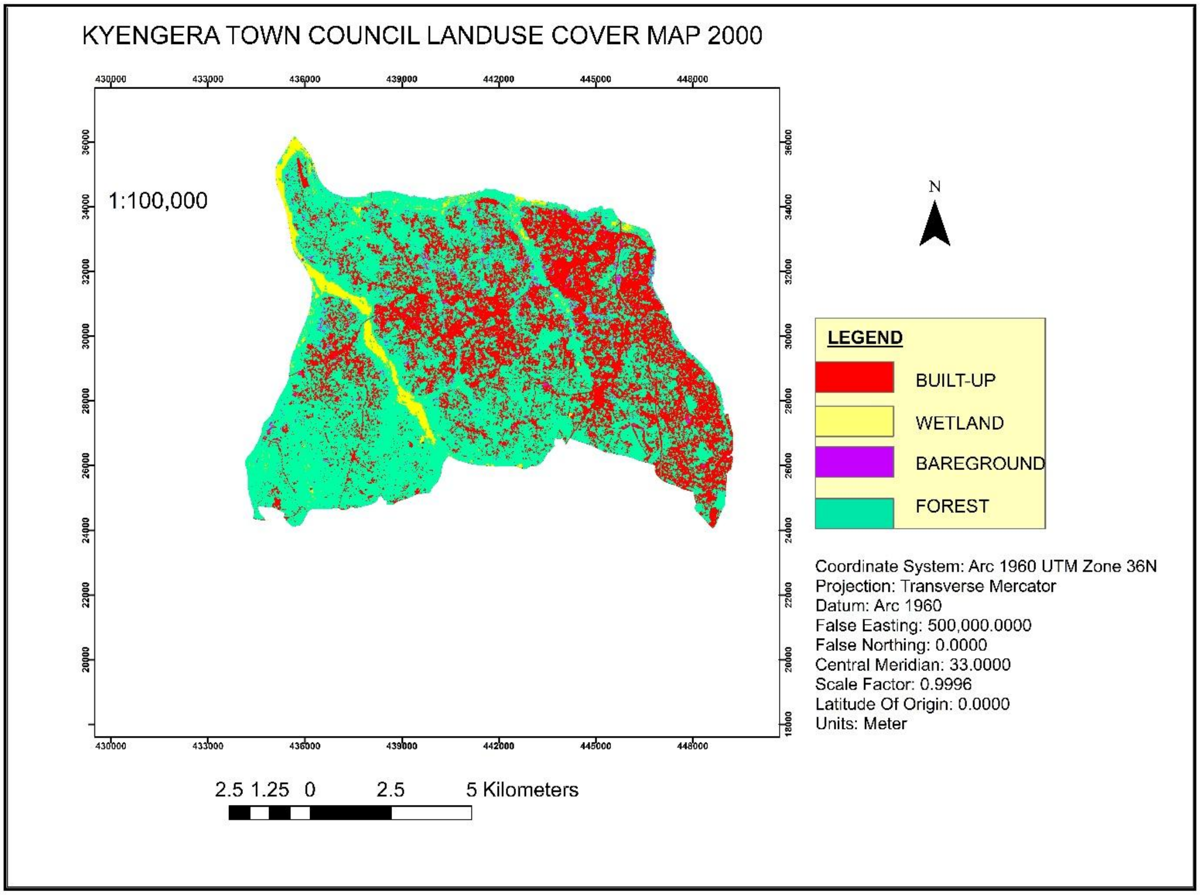
CHAPTER FOUR

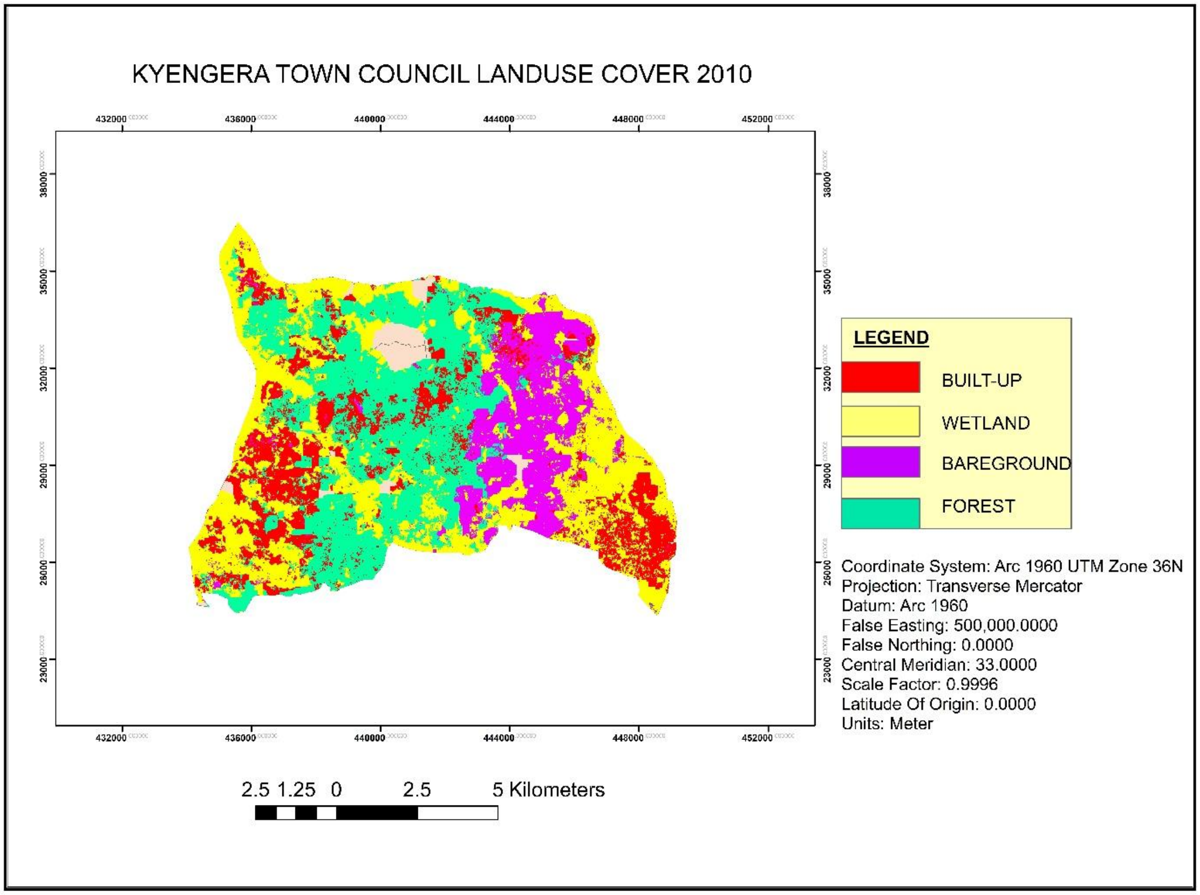
RESULTS AND DISCUSSION

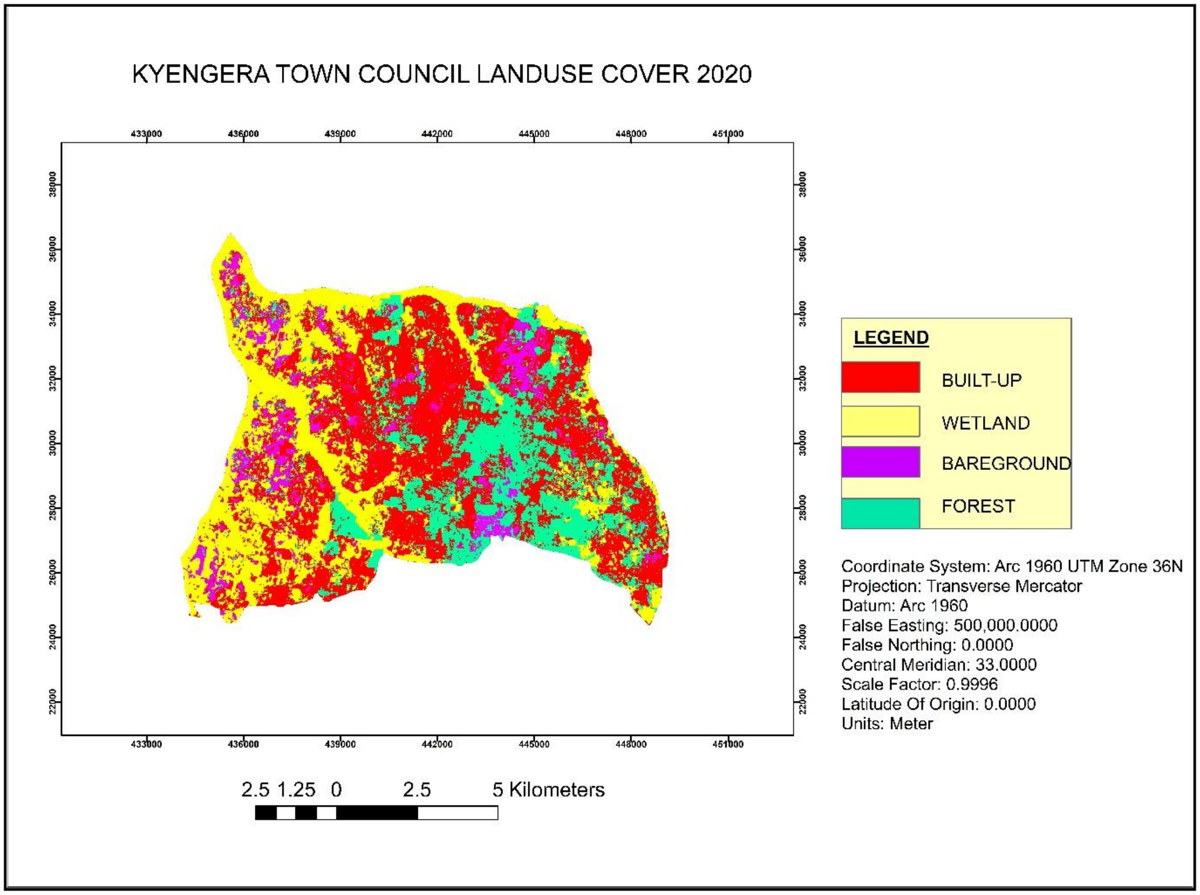
Land Cover Patterns for the Years

Prior to pre-processing, classification and post classification, six land cover classes were obtained for the test years. The land cover classes include; Built up, Sparse Vegetation, Thick Vegetation, Bare Ground, Water and others. Land cover maps showing the classes are as shown in the figures below.




KYENGERA TOWN COUNCIL LANDUSE COVER MAP 2000
1:100,000
N
LEGEND
BUILT-UP
WETLAND
BAREGROUND
FOREST
Coordinate System: Arc 1960 UTM Zone 36N
Projection: Transverse Mercator
Datum: Arc 1960
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 33.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
2.5 1.25 0 2.5 5 Kilometers


KYENGERA TOWN COUNCIL LANDUSE COVER 2010
432000
436000
440000
444000
448000
452000
38000
35000
32000
29000
26000
23000
LEGEND
BUILT-UP
WETLAND
BAREGROUND
FOREST
Coordinate System: Arc 1960 UTM Zone 36N
Projection: Transverse Mercator
Datum: Arc 1960
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 33.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
2.5 1.25 0 2.5 5 Kilometers



From the above maps, we can visibly see the landcover changes over the last two decades from 2000-2020.

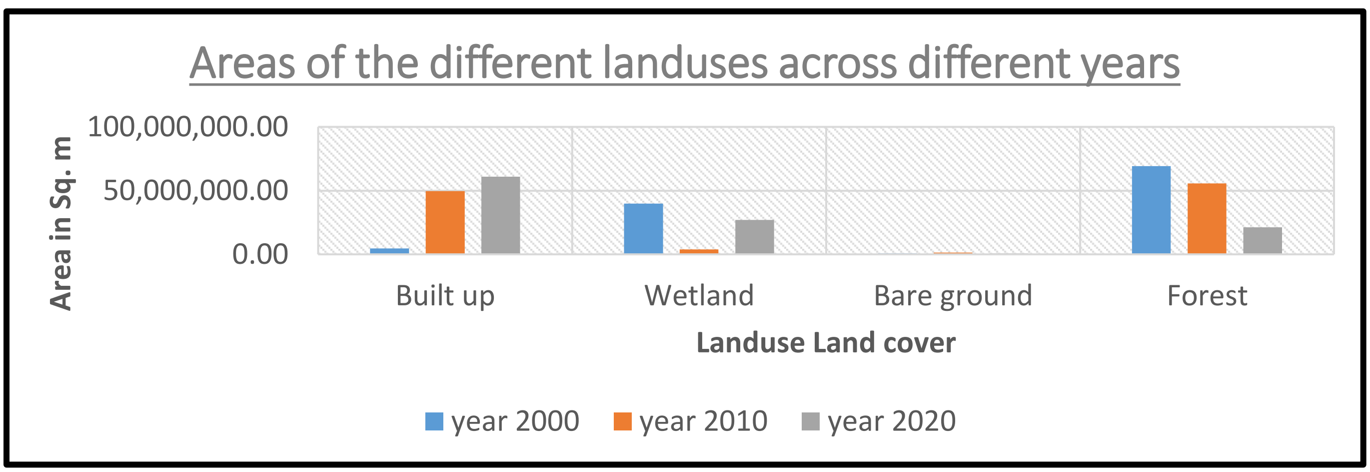


Table 4. 1:Areas changes in Square Meters

Land uses	**Change (2000 – 2010)**	**Change (2000 – 2010)**	**Change (2000 – 2010)**
Built up	45,044,404.483	11,173,863.061	56,218,267.544
Wetland	-36,055,964.200	-23,137,037.048	-12,918,927.152
Bare Ground	512,453.183	-492,865.3058	19,587.8773
Forest	-13,722,801.391	-32,290,121.362	-48,012,922.753

From the table above, it is evident that built-up area increased by over 56million square meters from 2000 to 2020, indicating a rapid urban expansion. Vegetation cover saw major declines reflecting significant environmental degradation. It is also evidenced that bare ground areas remained relatively stable with minimal net change over two decades.

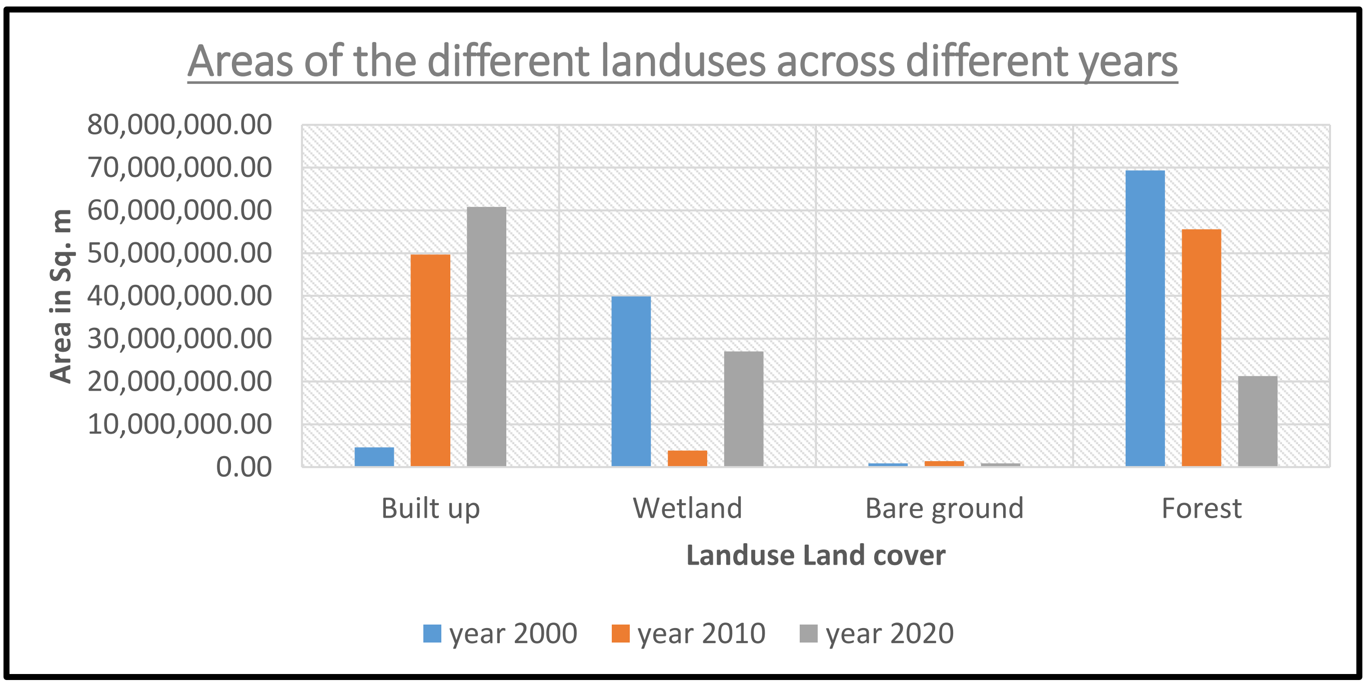


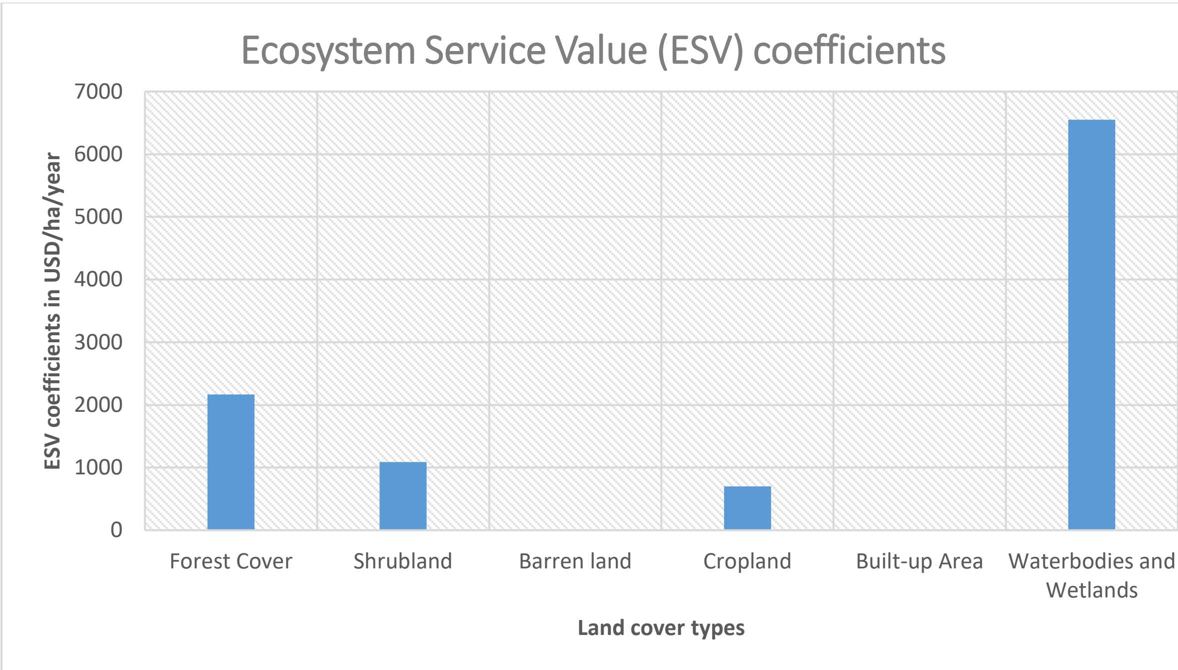
Table 4. 2:Areas Square Meters

Land uses	2000	2010	2020
Built up	4,601,855.103	49,646,259.586	60,820,122.647
Wetland	39,912,126.509	3,856,162.309	26,993,199.357
Bare ground	865,647.258	1,378,100.441	885,235.1353
Vegetation	69,306,261.916	55,583,460.525	21,293,339.163

Analyzing the above results, the built-up areas grew steadily from 4.6 million square metres in 2000 to 60.8 million square metres by the year 2020 while wetlands dropped sharply in 2010, then partially recovered to 27 million square metres by 2020. Bare ground oscillated slightly remaining approximately 0.9 square metres overall. Vegetation cover on the other hand plummeted from 69.3 million square metres in 2000 to 21.2 million square metres by 2020.

Table 4. 3:Results for Specific Objective Two

Land Use Land Cover type	Ecosystem Service Value (ESV) coefficients
Forest Cover	**USD 2168.84/ha/year**
Shrubland	**USD 1089.19/ha/year**
Barren land	**USD 0.00/ha/year**
Cropland	**USD 699.37/ha/year**
Built-up Area	**USD 0.00/ha/year**
Waterbodies and Wetlands	**USD 6552.97/ha/year**



The coefficients for quantifying Ecosystem Service Value (ESV) in this study were adapted from Xie et al.'s research on ecological asset valuation on the Tibetan Plateau, published in the Journal of Natural Resources in 2003. These coefficients were calibrated to reflect local environmental and ecological conditions, ensuring context-specific accuracy. This approach enhances the reliability of valuation results, supporting informed decision-making for sustainable ecosystem management. Utilizing established coefficients from reputable studies underscores the importance of building on existing scientific knowledge to improve assessment robustness and credibility.

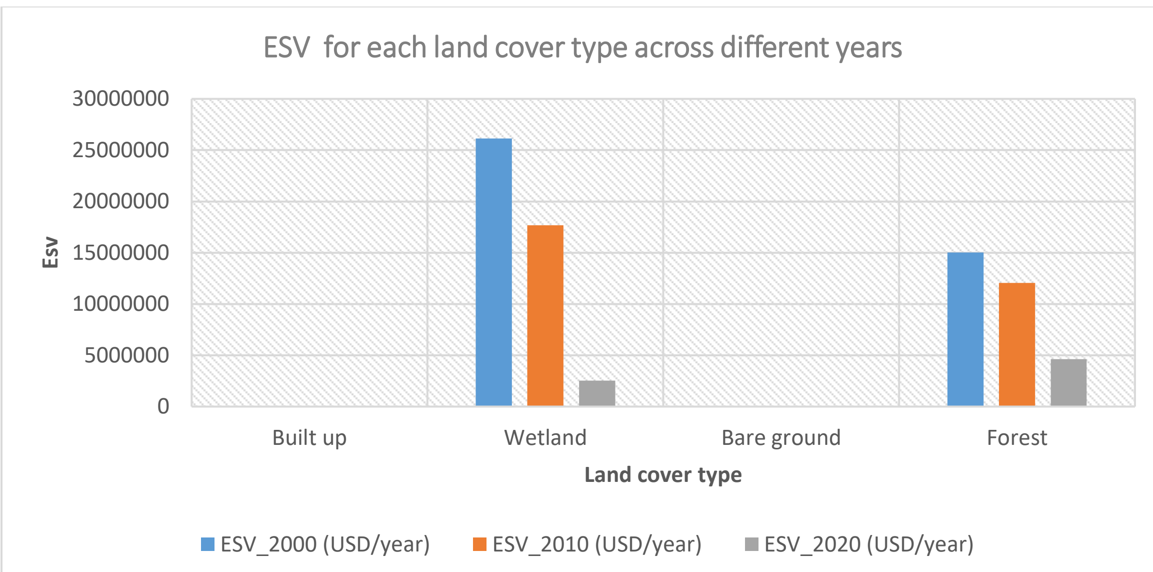
Table 4. 4:Areas in Hectares

Land uses	2000	2010	2020
Built up	460.1855103	4,964.6259586	6,082.0122647
Wetland	3,991.2126509	2,699.3199357	385.6162309
Bare ground	86.5647258	137.8100441	88.52351353
Vegetation	6,930.6261916	5,558.3460525	2,129.3339163

Table 4. 5: <u>Areas ESV values for each land cover type from 2000 to 2020</u>

Land uses	**ESV_2000 (USD/year)**	**ESV_2010 (USD/year)**	**ESV_2020 (USD/year)**
Built up	0	0	0
Wetland	26,154,342.33	17,688,574.65	2,526,934.39
Bare ground	0	0	0
Vegetation	15,031,438.25	12,055,249.77	4,618,181.71

ESV = Area (in hectares) x ESV Coefficient (USD/ha/year)



From the above graph and computation of the Ecosystem service value we have the following observations.

- Forest ESV consistently declined from approximately USD 15 million in 2000 to about USD 4.6 million in 2020.
- Wetland ESV drastically fell from over USD 26 million in 2000 to about USD 2.5 million by 2020.
- Built-up and Bare Ground areas consistently showed zero Ecosystem Service Value across all analyzed years.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study investigated the trend of the LULC and variation of ESV in Kyengera Town Council using remote sensing data for twenty years, from 2000 to 2020. According to the above analysis, the total value of ecosystem services was USD 49.19 million per year in 2000, where the most valuable land cover type was found to be wetland covers, having USD 26.15 million per year ecosystem service value. As for individual land cover types, all land cover varied from 2000 to 2020 and affected the total ecosystem service value of Kyengera Town Council. The land cover transitions show that built-up areas and bare land account for most of the loss in ESV. The increase in the ESV only occurs in the crop land-use class, and the degradation of vegetation cover in cropland and vegetation is the main reason for the loss in ESV in the study area.

LULC change is being driven by a combination of factors, including growing urban populations and their livelihoods, unplanned urban settlement, transportation congestion, air pollution, unmanaged solid waste disposal, and global climate change.

The global economic structure would significantly change if ecosystem services were adequately valued. The cost of goods dependent on these services would rise, and the world's gross national product would reflect a different volume and composition, emphasizing the importance of ecosystem valuation in economic assessments.

The study indicates that current ecosystem service valuations represent a static snapshot of a complex, dynamic biosphere. It offers valuable insights into regional variations in ecosystem service values over the past two decades. These findings can inform policymakers in urban development, ecosystem conservation, climate change strategies, and biodiversity preservation.

Recommendation

This study advocates for the strategic physical planning of growth centres to preserve ecosystem services through nature-based solutions integrated into urban development policies, plans, and funding mechanisms. It emphasizes the importance of considering regional heterogeneity and gradient analysis for precise ecosystem service assessment, thereby enhancing policy effectiveness and sustainable urban growth.

Developing a comprehensive physical plan is essential to address urban expansion, deforestation, loss of open spaces, agricultural land variation, and the decline of small to medium water bodies.

Some recommended plans are green roof space, rainwater harvesting, sufficient use of clean and green energy, and plantation in available spaces at large scales with the active participation of communities and coordination with governmental bodies to enhance the ecosystem services by increasing LULC dynamics.

This study clearly states the importance of Remote sensing and satellite imagery are vital for monitoring land cover changes and aiding ecosystem conservation.

The result of the study is useful in Land use and land cover model analysis evaluate their impact on ecosystems. Ecosystem Service Valuation (ESV) provides a robust monetary assessment, supporting policy decisions. It enables comparison of land classification accuracy across different techniques and models.

The most critically affected ecosystem service function in Kyengera Town Council provides a case study for research. Additionally, develop future scenarios considering urbanization and demographic growth to assess their impact on ecosystem service value (ESV). Findings should be expanded for comprehensive analysis. Since this study compared data from several other ecosystems, the information it contains will be crucial for future research and policy development for urban physical development plans.

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