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APPLICATION OF GEOSPATIAL TECHNOLOGIES IN MONITORING URBAN GROWTH: A CASE STUDY OF AHERO TOWN

BY

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A project report submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of The University of Nairobi.

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This research is submitted with my approval as university supervisor

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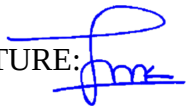
Prof. Dr.-Ing. Faith Njoki Karanja SIGNATURE:  DATE:01.09.2023

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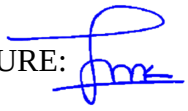
Prof. Dr.-Ing. Faith Njoki Karanja SIGNATURE:  DATE:01.09.2023

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Abstract

With over 80% of global GDP created in cities, urbanization may contribute to long-term growth if properly managed. Cities must act fast to plan for expansion and provide the fundamental services, infrastructure, and affordable housing that their growing populations require. Urbanization occurs at the expense of transformation of other landscapes, hence the process of urbanization has a large influence on landscape and ecosystem function.

This study aimed at mapping land use and land cover changes within Ahero Town over a period of 18 years using high resolution Google Earth Images at 6 years interval between 2003 and 2021.Random Tree Classification technique was used to classify the images.Change detection techniques was used to determine quantity and tendency of transition from one land cover class to another. TerrSet Geospatial Monitoring and Modeling System was used to carry out a prediction analysis of 2030.

The results obtained met the objectives of the study as they clearly indicated that the rate at which buildings have been increasing in Ahero town has been too high considering the significant decrease in the bare land. The conclusion drawn from the study indicate that the urban growth in Ahero town has significantly influenced the change in land use and the uneven growth experienced in the town. To improve on this, recommendations such as adopting GIS that would enable management through monitoring, managing and addressing the urban growth experienced in the town were suggested.

Table of contents

List of Tables

List of Figures

List of Abbreviations

GDP	Gross Domestic Product
NDVI	Normalized Difference Vegetation Index
AOI	Area of Interest
LULC	Land Use and Land Cover
GIS	Geographic Information System

CHAPTER 1: INTRODUCTION

1.1 Background

Over the last three decades, there has been drastic global population movement from rural to urban areas and is projected that the up-to 61% of world's population will move to urban areas by the year 2050 making population growth one of the most important driving force of change in any urban setting. According to 2017's UNECA report, East Africa is the least urbanized region in the Africa's Sub Sahara consequently with fastest urban growth. Rapid urban growth in Sub-Sahara brings setbacks in attainment of the Sustainable Development Goal 11 on developing sustainable urban communities and affordable housing for the public. Rapid urban growth has rendered most cities, small and medium towns unable to meet the growing demand of the social, economic and environmental population needs. UN-HABITAT 2014 report, indicate that despite significant overall growth, most cities in Africa continue to suffer under very rapid urban growth accompanied by massive urban poverty and many other social problems. Major cities and towns in Kenya face serious problems as a result of urban growth majorly exhibited in land use occasioned by public and private land use conflicts, inappropriate mixed land use, traffic jams due to inadequate capacity of road network, traffic control during peak hours, solid and liquid waste management and sighting of waste management facilities and disaster management as far as drainage during floods and fire outbreaks are concerned (Njiru, 2016).

Ahero town is facing serious planning and administrative problem which this study brings contemporary and advanced Remote Sensing technologies in monitoring the changes and effects that come with. Modelling the effect as well as forecasting the future pattern for purposes of formulating a working action plan that will see that sustainable development takes place in Ahero. Urban growth monitoring needs immediate address to achieve the global goal of sustainable cities as well as Kenya's vision 2030 (Obange & Wagah, 2019). Integrated mechanism that involves every stakeholder in decision making and planning guided by scientific facts and statistics from GIS based analysis ensures that every decision and policy formulation is sufficiently informed and guided. The Kisumu County Government through Governor Anyang' Nyongó unveiled Ahero as a town in November 2020. Ahero's new status will help it realize sustainable urban infrastructure development and create economic opportunities to the people to reduce pressure in the city.

1.2 Problem Statement

Urban development within Ahero Town is currently uncontrolled without any spatial plan and with great challenges in terms of pollution from liquid and solid waste, poor drainage and floods, and urban sprawl into public land along the River Nyando and the highway. The town currently lacks an approved spatial development master plan to guide development and govern decision making on land use and management. This has led to development approvals on need basis in disregard of physical planning requirements as provided for in the Constitution 2010, physical land use and planning act of 2019 and county government act of 2012. For years now, there has not been any formal change of user for purposes of development in those areas whose use over time has changed through assimilation into the town leading to serious conflict between land use and the adopted town plan.

Lack of political goodwill, financial and expatriate investment and urban management policy guide in steering sustainable urban growth from both national and county government has led to delayed implementation of respective master plans. Budgetary allocation for monitoring and development of prediction models for urban growth, either by government or the department is minimal making it less a priority. This has led to use of older techniques of measuring urban growth which do not give account to previous and current status as well as projected growth for mitigating the future expected negative impacts of sprawl.

Slow or partial adoption of new scientific techniques such as GIS and Remote Sensing in the government and private sector has also become a hindrance towards realization of better planning and management of development. The responsible departments have stuck on the old techniques which over time have become unproductive and inefficient in monitoring contemporary development and sustainable growth needs or expansion of Ahero Town.

Several studies have been done on urban growth within Kisumu County. Of particular interest is the Urban Sustainability Review by SymbioCity which was conducted for Ahero Town. The mission of the SymbioCity approach for Ahero is to promote, facilitate and coordinate activities of different actors towards sustainable development and poverty eradication in Ahero Town.

Mapping of the land use and land cover changes is yet to be carried out. This study aims to do change detection that will be used to monitor urban growth in Ahero Town. The results will be shared with Kisumu County Planning Department, to help inform further formulation of policies for sustainable development of the town. It is important to note that similar studies have been conducted by various scholars from different background on different towns around Kenya. However, a specific focus on Ahero town is yet to be done as most studies focus on aspects to do with education and agriculture. This study would thus shed light to the rather unforgotten aspect that is affected by the rapid growth in Ahero town.

1.3 Objectives

1.3.1 Main Objective

The overall objective of the study was to monitor urban growth by applying geospatial techniques, using Ahero Town as case study.

1.3.2 Specific objectives

The specific objectives were to:

i. Review factors contributing to urban growth in Ahero Town.

ii. Map land use and land cover change between 2003 and 2018 at 5 years interval.

iii. Assess the rate of urban growth and conversion of other land use forms to built-up.

iv. Predict land use and land cover of Ahero Town by 2030.

1.4 Scope and Limitations of the study

This study aims at monitoring urban growth within the delineated Ahero Town boundary over a period of 19 years using Landsat Images of 2003, 2008, 2013 and 2018.Aspects of growth will be measured using land use and land cover changes based on four classes: Built-up areas, Vegetation, Farm land & bare land.

The accuracy and resolution of the satellite images acquired stands as a great limitation for this study. In addition, urban growth monitoring studies may not capture the complex social, economic and political factors that drive urbanization.

1.5 Justification of the study

Urban growth monitoring studies are essential for a number of reasons. They provide policy makers, city planners and developers with crucial information about the rate and pattern of urban growth in a given area. This information can be used to guide future development plans, identify areas that are at risk of becoming overcrowded, and assess the need for additional infrastructure and services.

In addition, this study will help to identify areas of environmental concerns. As towns expand, they often encroach on natural habitats, and this can have a significant impact on the local ecosystem. Monitoring urban growth, will help researchers identify areas where development may be having a negative impact on the environment, and takes steps to mitigate these effects.

Further, this study can be used to identify areas where social and economic disparities are most pronounced. For instance, if certain neighbourhoods are experiencing rapid growth while others are stagnating, this may indicate that there are underlying social economic factors at play that need to be addressed. By identifying these disparities, policy makers and community leaders can work to promote more equitable development.

1.6 Organization of the report

This report is organized into five chapters. Chapter one contains the introduction which gives a background of Ahero town and its growth as a town, the problem statement and objectives to be met at the end of the project. The scope of this study and limitations are also discussed in this chapter. Chapter Two deals with literature review, which mainly outlines urbanization on a global, regional and national level, factors that led to urbanization, the challenges and the role of geospatial techniques and monitoring urbanization. Chapter Three is the methodology, describing the various stages of data processing and the tools used. Results, analysis and discussions are in Chapter Four of this project and Chapter Five ends with the conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1. Urbanization

Urbanization is a concept which refers to the increase in the number of people who reside in cities, towns and other urban dwellings. There are many reasons that lead to urbanization. However, top of this classification is internal migration. In this, the movement of people is from rural areas to urban areas. Often time the movement is caused by various reason such as search for better living conditions, unemployment, internal conflict or civil wars and a general lack of technological advancement in the rural areas (GU, 2019). Moreover, in the latter cause of rural urban migration, the low uptake of technology and other industrialization elements in the rural areas unlike in the cities, means that there would be a notable slow trend in development in general and creation of employment and better living conditions as a whole.

As indicated above, the three main determinants of urbanization can be broken down into the natural increase in population size and the transformational element of rural areas into urban setting through industrialization and technology advancements. In line with this, it is important to note that, there are different ways of measuring urbanization (GAO & O'Neill, 2020). The most notable tenets to measure urbanization include population growth, push and pull factors, rural-urban migration, socio-economic expansion rate and overall industrialization, For the purpose of this thesis research, the review into the factors that are hindering the growth of Ahero town into becoming a full-fledged city or urban setting will outline among many other issues the elements of population, slow technology growth uptake , lagging industrialization and an overall stagnated economic aspect to its development. Ultimately without a notable growth in these elements then, an area much like Ahero cannot be clustered as an urban setting.

2.1.1 Global

According to a recent report made by the World Bank, approximately 56% of the world's population which equates to about 4.4 billion people live in urban cities. Despite the numbers being high, the trend is expected to continue and the projected statistics by 2050 is expected to be double the current numbers. It is expected that by 2050, about 7 people out of every ten people would be living in cities (The World Bank, 2022). Over the years, urbanization as proven to be the best move for people, the economies, education, transportation and other sectors. For instance, through urbanization about 80% of the GDP is facilitated thus guaranteeing sustainable growth especially through the high rates of productivity and innovation.

However, it would be important to acknowledge the fact that the rate of growth of urbanization is still slow especially as the demands for amenities such as affordable housing, transport systems, reliable infrastructure and other services such as employment keep accelerating. Countries around the world still face the pressing challenge of having proper urban planning especially considering the fact that, once urban areas are set up the plans and patterns tend to influence the nature of livelihood in such regions for decades some even centuries which in reality is not sustainable. The expansion of urban land consumption outpaces population growth by as much as 50%, which is expected to add 1.2 million km^2 of new urban built-up area to the world by 2030 (The World Bank, 2022). The energy consumption rate of urban areas and cities is equally significantly high sometimes exceeding the supply thus creating outage sprawls. Additionally, it is critical to note that, cities single-handedly contribute to over 70% of greenhouse gas emissions which is a great concern especially in the face of severe climate change.

The statistics above give a glimpse into the nature of urbanization globally. All factors withstanding, there are several factors that contribute to the growth or cities, most often than note these factors vary from one country to the other (Gao & O'Neill, 2020). Developing nations often exhibit better results when it comes to the causes of urbanization as well as the growth rate of urbanization (The World Bank, 2022). Such nations have better working systems, urban planning and developed economies which support such growth unlike in developing nations where the circumstances are mostly different.

2.1.2 Regional

A focus on the regional perspective of urbanization with a keen focus of Africa indicates that Africa has experienced transformative growth as a result of urbanization and this is forecasted to continue throughout the 21st century. As compared to other continents, Africa has some of the fastest urban growths despite them being the youngest and smallest cities. A majority of this growth is mainly witnessed in small and medium sized towns. It is expected that by 2050, the continents urban region would be home to over 950 million people OECD/UN ECA/AfDB (2022).Urbanization has had a great impact on the rapid growth of most African countries as these cities contribute to the social, economic and political landscapes in such nations. According to Organization for Economic Co-operation and Development report, it is evident that urbanization has continued to the improved standards of living among city dwellers (OECD/UN ECA/AfDB, 2022). Moreover, the socio-economic dimensions also indicate that most of the African cities tend to do better than the countries in which they are located and the gap in performance in most situations is large. The continent's 2030-2063 development agenda as well as the projected integration within the continent would thus be effectively accelerated by the support directed towards urbanization by both the local and regional heads (OECD/UN ECA/AfDB (2022). The positive effects of urbanization has not only affected cities but the effects have also spilled over into rural areas that are within the proximity of cities thus contributing to a wholesome growth in most African countries.

However, with such benefits come various challenges. Just as witnessed in the global perspective, African policy makers are faced with the obvious challenge of planning, financing and managing the growth of urban areas. The effect is widespread both in the local and the national level. Besides, several places within Africa and beyond have also experienced the negative perception that dwellers have of the externalities of urbanization. As a result, this perspective has largely affected the proper implementation of the set strategies towards African's development.

2.1.3 National

The current location of Ahero town has strategically situated it to be a transport node thus experiencing heavy traffic. To add to this, the town has also been a hub for different kinds of trade as well as other activities. However, the town still has a long way to go when it comes to aspects of urban planning and design. The main mode of transport within the town is the use of bodaboda and there are hundreds of bodaboda riders both for commercial purpose and for personal use. One of the greatest challenges is with regards to the transport system whereby there is no designated parking space for the cyclist, and handcarts and matatus therefore being forced to park dangerously on road reserves. Also, the roads that lead to the settlements are not graded as expected neither are their marked in a visible manner. The other challenges is that the towns roads are narrow and have been neglected thus being non-motorable. The roads are also poorly drained and the street lights are either missing or not working thus making such streets to be very dark and dangerous for motorists and pedestrians at night.

The local industry is made up of various activities, however, the main activity is agriculture with a focus on rice farming. Farming has been largely facilitated by the existence of the River Nyando which flows through central Ahero. The water from the river is used by farmers for the purpose of irrigation in the rice fields. Nonetheless, the river is not utilized for any water-based transport, and it is eroded and polluted by liquid and solid waste.

The locals own huge tracts of rice fields where they farm rice for both personal use and for commercial purposes within the county as well as to other neighboring countries across the nation. The local industry has been experiencing tremendous growth over the years and this has largely been contributed to by the existence of the Nairobi road to the north of Ahero which has given the town a newly found impetus. However, according to the national statistics, about 63.7% of the population is estimated to be below the poverty line and that the dependency ratio is very high ranging at 100:99.

The educational amenities in the town could be considered as being relatively enough although a lot of work still needs to be done. The town dwellers have access to at least two secondary schools, three primary schools and vocational training center which is still a low number for the average population of about 10,000 dwellers. The internet connectivity and access to technology has also

been very poor with only a few people having access to amenities such as smart phones and personal computers. As it stands, the internet penetration is 3% and the available connection is also weak. The town dwellers have however resorted to alternative options such as boosting their connectivity using WAP enabled phones, some seeking the services of the few cyber cafes and internet facilities which have been set up within the area.

The settlement in Ahero town is made up of informal settlements by the dwellers on freehold titles lands. A structural plan on the physical planning for the town was developed in 1977 with the main aim being to set up the town for improvement into the next few decades. However, the plan has not been executed as documented because of various reasons. One of these is the fact that, as proposed, the land acquisition process was not done. Also, the zoning policy and the land management system have not been put in place and this problem not only affects Ahero town but also other towns in the country. It is safe to say that, the town lacks an urban plan that would effectively guide the ever increasing population, economic activities and the growth in urbanization. As such, the realizable growth of Ahero town has been such a challenge especially considering the fact that the necessary facilities and amenities lack. Additionally, the town lacks a spatial framework which has since resulted to uneconomical land subdivision and unstructured development. As such, the town lacks the planning unit and most of its approval are done at the County Headquarters therefore contributing and foreseeing a delay in most of the approvals for development. The public has also been involved before the inception of various projects and the town's annuals budget. However, better structures and planning need to be put in place as the public attendance has been wanting. Having well designed consultation workshops that could accommodate a majority of the people regardless of their social differences.

Housing

Ahero town, just as most towns in the country has witnessed an increase in the construction of new buildings as well as a change in the design adopted for the construction off houses and the building materials used. On average, sixteen developments are made each month but the approval for such developments are yet to be made. The main reason behind this could be that, most constructions are temporary and the materials used include clay, iron sheets and wood. The progress today indicates that people have considered the construction of more permanent buildings and use materials such as stones, bricks and cement in their construction.

Also, unlike one or two decades ago, when most of the land use was for agricultural purposes, the drift has been to residential use, institutional as well as commercial and other economic activities such as petrol station. Most people have however settles on the agricultural land as an influence that their culture of "goyo dala" (the setting up of a cultural home upon marriage) has had on them. Also, the poverty levels in the area has contributed to such effects as most people end up selling their lands and settling in areas meant for agricultural purposes thus contributing to more land fragmentation. Also, most of the people living in Ahero own parcels of land but still lack title deeds.

Flood Management

The topography of Ahero town is that, it is a flat area and it tends to gently slope into the Lake Victoria. It is also important to note that the town lies right at the base of the Nandi escarpment. As such, most of the rain water tends to run off into the town through various channels but, mostly through River Nyando. Most often than not, the river over flows into the human settlements thus flooding is one of the biggest problems being experienced in the town. Ahero town experiences tropical climate and floods especially during the rainy seasons from April to June and that between November and December

The socio-economic activity in the town have suffered the most. When it floods, families are displaced, businesses suffer losses and transportation becomes almost impossible. The drainage system in the town is poorly factored in and the polarity of the soil in the region is equally very low. Nonetheless, it is interesting that, despite the fact that most of the dwellers in Ahero town are fully aware of the flooding menace they continue to stay in the same lands as most of them are generational lands therefore leaving them with no alternative for the future of themselves and the next generations. Also, there is the section of the dwellers who have expanded their settlement in to riparian area thus living along the River banks. The authorities are yet to ensure that such settlements ate redirected especially because the River always breaks its banks during the rainy season. The settlement practice has also contributed towards extreme water pollution as most of the plastic waste is released into the river. This has also contributed further to the flooding situation.

Additionally, the market area which is often so congested also lacks proper drainage system. As such, when hit with flooding, it becomes almost impossible for the people to continue with the business as usual. This has thus made it hard for people to effectively make a living in the flood prone area thus the standards of living in the town seems to have stagnated or deteriorates over time.

The possible solutions for the flooding menace has never been put in place. Nonetheless, various organizations such as World Vision, Kenya Red Cross and other government authorities often assist the dwellers with the evacuation process, provision of shelter, food, education and security. The Kisumu County Government has also put in place proper measures that aim at combating the menace. The government has also collaborated with other organizations to engage in activities such as desilting, dyking and creating more channels for the flood water. Also, gabions have been constructed along the river bank to help with controlling the water and its effects. The national government has also put in place a flood control program which goes a long way into assisting the community in the construction of trenches in the town. The program is dubbed the "Food for Work" initiative.

2.2 Factors that lead to urbanization

Urbanization can be contributed to by various factors. However, the three main factors that lead to urbanization include growth of population, poverty and lastly it's the economic effect of urbanization. The growth of population has been increasing at a very fast rate over the years. The result of this is that space ought to be created for the people to reside, work and interact with others. It is important to first note that, there are three components of urban population growth (Aikaeli, Mtui & Tarp, 2021). These include the natural growth of the urban population, the rural to urban migration and lastly the reclassification of areas that were previously recognized as a being rural (Bodo, 2019). As such, as the natural growth offers a base for the increased growth rates in such urban locations, the migration and reclassification supplements the growth further.

The other factor that leads to urbanization is poverty. The need for people to meet their basic and secondary needs often sees to it that such individuals are forced to move to new locations in search of employment as well as in such of favorable conditions to set up businesses. As it is, poverty affects a majority of people across different countries even in countries believed to be developed.

In as much as the main focus of poverty is always the income levels where poverty is defined as the inability to access basic needs such as the supply of water, sanitation, health care and proper housing among others (Bodo, 2019). However, to other people poverty could be social in that, they are unable to get access to secure surroundings and basic civil and political rights. All these reasons often contribute to migration to urban areas and to some, taking the long root of string to remodel and reclassify their rural areas to urban areas.

The third factor that influences urbanization is the economic effects. As witnessed in the recent past, various rural areas have been urbanized as more people consider modern industry as opposed to agriculture and other traditional local services (Aikaeli et al., 2021). Also, according to research, it is evident that the ecology in urban areas is more conducive for specialized goods and services especially to the local market (Bodo, 2019). Amenities such as provision of financial services, skilled and unskilled labor, transportation, accumulated capital among other advantages often attract growth of urbanization.

Other factors that have led to growth of Ahero town include;

Agricultural Opportunities: Ahero Town is situated in a fertile agricultural region, making it attractive to farmers and agribusinesses. The availability of arable land, favourable climate, and proximity to water sources like Lake Victoria make it a suitable location for various agricultural activities, such as rice and vegetable farming. The agricultural sector attracts people from rural areas, leading to population growth and urbanization.

Employment Opportunities: The agricultural sector in Ahero Town provides employment opportunities, not only for farmers but also for people engaged in agro-processing, marketing, and distribution. The presence of agricultural industries and associated businesses attracts people from surrounding rural areas in search of better job prospects. This influx of people contributes to the urban growth of Ahero Town.

Infrastructure Development: Improved infrastructure plays a crucial role in urban growth. Ahero Town has witnessed investments in infrastructure development, including roads, bridges, and irrigation systems. These developments enhance connectivity, facilitate trade, and promote economic activities, making Ahero Town an attractive destination for businesses and residents.

Proximity to Regional Centers: Ahero Town's strategic location near larger urban centres, such as Kisumu, plays a significant role in its growth. Kisumu, the third-largest city in Kenya, is an economic hub in the region and offers various services, employment opportunities, and amenities. Ahero Town benefits from its proximity to Kisumu, as it becomes a desirable residential area for individuals seeking a balance between rural and urban lifestyles.

Government Initiatives: Government policies and initiatives can influence urban growth. Public investments in infrastructure, such as schools, healthcare facilities, and utilities, improve the quality of life and attract people to settle in Ahero Town. Additionally, the government's support for agricultural development and the provision of subsidies or incentives to farmers can stimulate economic activities and contribute to urban growth.

Migration and Rural-Urban Shift: Rural-urban migration is a common trend in many developing countries. People from rural areas often move to urban centres in search of better employment opportunities, education, healthcare, and improved living standards. Ahero Town, with its agricultural and economic prospects, experiences migration from surrounding rural areas, contributing to its urban growth.

Social and Cultural Factors: Ahero Town's social and cultural aspects also play a role in urban growth. The town may have historical or cultural significance, attracting tourists and visitors. Additionally, the presence of social amenities such as places of worship, community centers, and recreational facilities can make Ahero Town an attractive place to live and contribute to its growth.

2.3 Challenges of Urbanization

Urbanization locally, regionally as well as globally face various challenges that have significantly inhibited the desired results. While urban growth in Ahero Town brings numerous benefits, it also presents several challenges that need to be addressed for sustainable development. Some of the challenges associated with urban growth in Ahero Town include:

Overpopulation whereby many people have migrated to areas believed to be more advanced than the rest. One of the main reason attributed to overcrowding of urban areas is the search for employment or a source of livelihood (Anwar et al., 2020). The effect of this is that, most of these areas are often unable to accommodate such huge numbers thus forcing people to compete for the limited and scarce resources for example water, electricity and transport among several other amenities.

Poor housing conditions have been recorded as one of the challenges of urbanization. Just as mentioned above, in most cases, people tend to scramble for the scarce resources. As witnessed from the analysis of major cities and urban areas, most of them fail to plan for a surge in the population (Salim et al., 2019). The aftermath is that the available houses become overpriced and only a few, well to do individuals end up getting lucky with their housing situation leaving the majority who are often unemployed and lack a source of income struggling to find affordable and decent housing within the urban areas.

Moreover, sanitation problems would equally be a menace in such a situation. In most urban areas locally, starting with the capital city of Nairobi, sanitation problems are very rampant and this is contributed to by the overpopulation and the setting up of alternating housing by developing slums. The main challenge often emanates from the fact that the local government is often unable to set up and manage a proper sewerage system despite the rapid growth in the population (Salim et al., 2019). Besides, in most urban areas, resources are scarce thus making it harder for the local government to set up such sewerage systems (Anwar et al., 2020).The sanitation problem is considered one of the worst challenges as its effect metamorphosed into being an environmental problem especially when the sewage waste is released into the water sources. The health of the urban dwellers, the animals and even the water sources are thus endangered and this contributes to public health problems.

The other challenge is the degradation of the environmental quality which has affected most urban areas both locally and regionally. The overcrowding of people in urban areas and the scramble for scarce amenities has led to the reduced quality of basic things such as air, water, land. Noise pollution has also become a problem that urban dwellers are forced to live with (Pradhan et al., 2021). However, the main problem of these increased population is that, with poor urban planning, the environmental conditions keep deteriorating by the day. A case in point is Nairobi city which has increasingly experienced dumping even in water sources such as the Nairobi river thus making it almost impossible for the city dwellers to enjoy clean air, clean water and beautiful sites of the city (Salim et al., 2019).Most importantly, the growth of urban areas has seen to it that forests and natural habitats are encroached for various reasons such as creating space for the construction of building as well as the acquisition of raw materials for construction such as timber from the fell trees.

Housing and Infrastructure: As the population grows, there is an increased demand for housing and infrastructure. Ahero Town may face challenges in providing adequate housing options and basic amenities such as water supply, sanitation, electricity, and transportation. The existing infrastructure may become overstretched and struggle to meet the needs of the growing population.

Urban Planning and Land Management: Rapid urban growth can put pressure on land resources and lead to haphazard development. The lack of proper urban planning and land management can result in informal settlements, inadequate land-use allocation, and encroachment on agricultural land. This can lead to issues such as land disputes, inefficient land use, and inadequate provision of essential services.

Traffic Congestion and Transportation: Increased population and economic activities can lead to traffic congestion and transportation challenges. Ahero Town may experience inadequate road networks, limited public transportation options, and inefficient traffic management. This can result in increased commuting times, reduced mobility, and environmental pollution.

Environmental Impact: Urban growth can have adverse environmental consequences. In Ahero Town, unregulated urbanization may result in deforestation, loss of natural habitats, and degradation of ecosystems. Increased pollution, improper waste management, and depletion of water resources can further strain the environment and impact the overall well-being of residents.

Social Services and Facilities: As the population grows, there can be a strain on social services and facilities such as schools, healthcare centers, and recreational spaces. Ahero Town may face challenges in providing adequate access to quality education, healthcare services, and community facilities, leading to potential disparities and inadequate provision of essential services.

Employment and Livelihood Opportunities: While urban growth can create job opportunities, there may be challenges in ensuring equitable access to employment and livelihood options. Ahero Town may face issues of unemployment, underemployment, and limited skill development opportunities, especially for the growing youth population. This can lead to social and economic inequalities within the urban area.

Social Cohesion and Cultural Preservation: Urban growth can result in demographic changes and the influx of people from diverse backgrounds. Preserving social cohesion and cultural identity in the face of rapid urbanization can be a challenge. Ahero Town may need to focus on fostering inclusivity, promoting cultural heritage, and maintaining social harmony within the community.

2.4 The role of geospatial techniques in monitoring urbanization

To monitor the environment and make proper management, observing and analyzing changes in the infrastructure and environment are significant. One of the most efficient techniques for analyzing changes in urban areas is remote sensing. The usage of multi-time data from various sources is necessary for quantitative and qualitative change detection.

Change detection results will be influenced by many factors, e.g., the geometric relationship between the images used, the quality of the data, the type of infrastructure or the complexity of the environment, the techniques or algorithms used, the type of classification, as well as the skills and experience of the analyst(Lu et al., 2004). The first change detection methods were based on the pixel-based approach, i.e., on a comparison of pixel values. Over time, along with improving the resolution of images and increasing the images' details, feature-based methods have been developed (Ilsever & Unsalan, 2012).

Therefore, change detection methods can be divided into digital processing, i.e. Algebraic operations (image differencing (Karthik & Shivakumar, 2017), image rationing (Khanday &

Kumar, 2016) image regression (Afify, 2011)), image transformations (spectral indices (Xie et al., 2014), i.e., NDVI (Mutanga et al., 2023); Principal Component Analysis (Abdi & Williams, 2010), classification (Wu et al., 2017)) and visual analysis, where the analyst's knowledge is the crucial element. However, visual analysis is time-consuming, especially when analyzing a large area or when imagery data is very detailed (Zhu & Woodcock, 2014).

There are many techniques for urban land cover automatically mapping. These techniques can be broadly grouped into two general types: those based on the input data classification, including pixel- and object-based classifications and those based on directly segmenting the indices, such as the commonly used normalized difference vegetation index (NDVI), normalized build-up area index (NDBI), and their modifications. Moreover, in recent years, integrated artificial intelligence (AI) techniques can be used to detect changes. AI techniques, also called machine intelligence or machine learning, can perform various data-processing tasks better. It can be defined as a system's ability to interpret external data correctly, learn from such data, and use those learnings to achieve specific goals and tasks through flexible adaptation.

For this study Random tree classification was used. It is a machine learning algorithm that uses an ensemble of decision trees for classification of tasks. It is often applied to multispectral or hyper spectral imagery to classify different land cover types or detect specific objects or features. Training data is required to train the random tree classification model. This involves manually labelling or digitizing representative samples from the remote sensing imagery. The training data should include different land cover classes or objects of interest. Once the training data is prepared, the random tree classification algorithm is applied. Random subspace selection is used to randomly choose a subset of features from the extracted feature set. Then, multiple decision trees are trained using bootstrap aggregating, where each tree is trained on a randomly selected subset of the training data. The trained random trees are used to classify the remaining unlabelled pixels or regions in the remote sensing imagery. Each tree provides a class prediction for each pixel based on the selected features. The final prediction is determined by aggregating the predictions, typically through voting or weighted voting. Accuracy assessment methods, such as ground truth validation or error matrix analysis, are used to evaluate the performance of the classification and assess its overall accuracy.

Random tree classification in remote sensing offers several advantages, including:

Accurate Land Cover Classification: Random tree classification can effectively handle complex spectral and spatial patterns present in remote sensing imagery, leading to accurate land cover classification results.

Robustness to Noise and Variability: Random tree classification is robust to noise, outliers, and variability in remote sensing data, making it suitable for handling data from different sensors, atmospheric conditions, and acquisition dates.

Handling High-Dimensional Data: Random tree classification can handle high-dimensional remote sensing data, such as hyper spectral imagery, by selecting relevant features and reducing dimensionality.

Interpretability: Random tree classification provides interpretability by estimating the importance of input features, allowing users to understand which spectral bands or derived features contribute most to the classification process.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

Ahero is an agricultural town in the County of Kisumu. Its geographical coordinates are 0° 11' 0" South, 34° 55' 0" East. Ahero is located 20 kilometers east of the county capital, Kisumu, in Nyando sub-county. Two major roads meet at Ahero, the B3 road from Nakuru to Kisumu and A1 road from Tanzanian border. The Nyando River flows through central Ahero and helps irrigate its many rice fields. The town has a retail market serving as a main trading center for food and goods coming from Kisii, Homabay, and Nandi.

The delineated town boundary is as shown in figure 3.1 & 3.2 below;

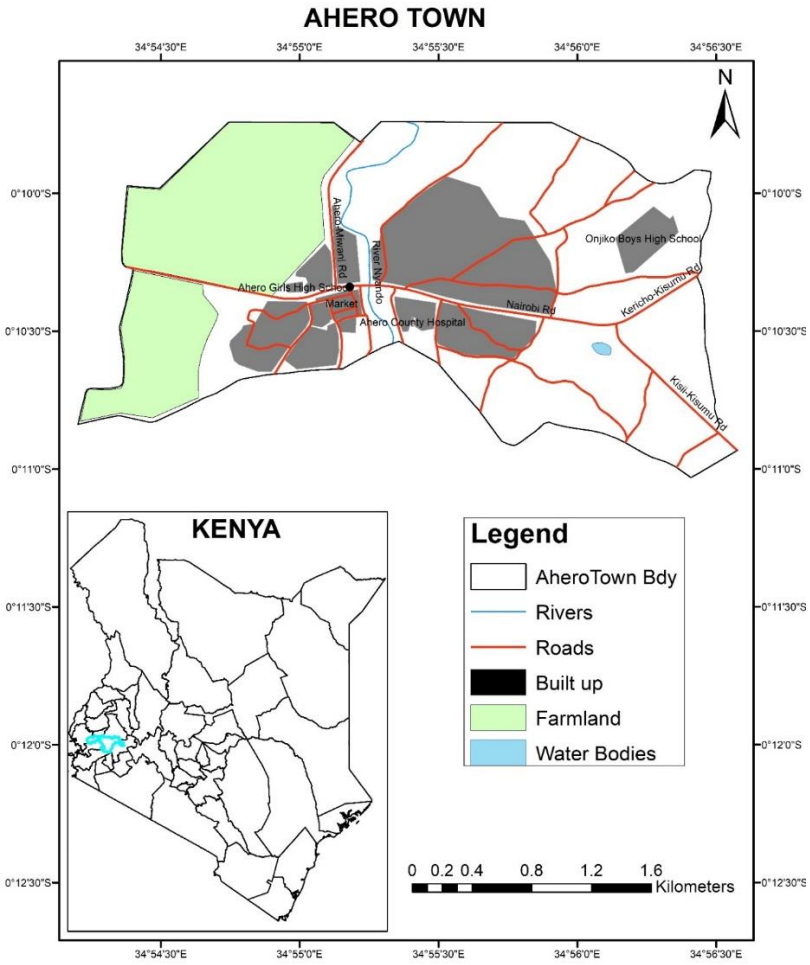

Figure 3.1: Study Area

Figure 3.2: An aerial view of Ahero Town with River. Nyando running through.

3.2 Data Sources and Tools

3.2.1 Data Sources

Table 3.1: Datasets required and Data Sources

DATA SETS	**DATA SOURCES**
High resolution Google Earth Images	Google Earth
Kenya Administration	County Government of Kisumu
Town Boundary shape file	County Government of Kisumu

3.2.2 Tools

A combination of hardware and software was used to generate this project. Hardware refers to the physical components and software refers to the programs that were used.

Hardware

i) Laptop which has the following specifications; 500 Gigabyte Hard disk drive, an Intel Corei5 Processor with a 2.50 Gigahertz speed and a 4 Gigabyte Random access Memory (RAM).

ii) Garmin 12 XL hand held GPS Receiver, for collecting ground-truthing data within Ahero Town.

iii) A HP Deskjet color printer for printing the final report.

Software

Table 3.2: Software Used

Software	**Use**
ArcGIS 10.8 and QGIS 3.28	Creating LULC maps for 2003-2021.
TerrSet	Predicting LULC for 2030.
Microsoft Office	Typing and editing of this report & Creation of graphs.
Erdas Imagine	Change Detection

3.3 Methodology

3.3.1 Overview of Methodology

For this project, data was first acquired from the outlined sources and a reconnaissance done to the study area. The images were georeferenced and subset using the delineated town boundary of Ahero Town. Random Tree Classification was then carried out to detect changes in LULC followed by ground truthing to verify classification results. Ground truth data acquired was then used to conduct accuracy assessment and validation of results. Lastly, TerrSet was used for prediction of 2030 LULC.

The project design flow is as shown in figure 3.3.The steps included Data acquisition & Reconnaissance, Image Preparation- Georeferencing & Sub setting using Ahero town boundary, Image Processing - Random Tree Classification, Accuracy assessment & Validation of results, Analysis of change detection, Ground Truthing and finally Prediction of 2030 LULC.

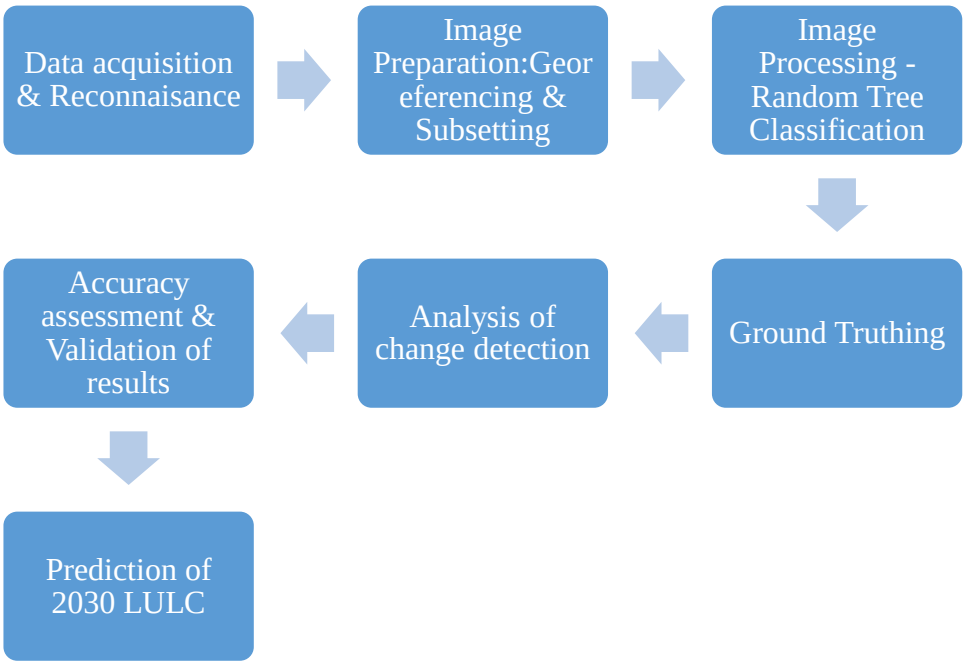

Figure 3.3: Project Design Flow

3.3.2 Data acquisition

Primary data derived as Google earth images in Geotiff format from Google Earth was used for land use land cover classification in ArcGIS software. Google Earth images were chosen over other satellites due to its high resolution over a small study area.

The delineated Ahero Town boundary shapefile and other ancillary data were obtained from Kisumu County Department of Planning.

3.3.3. Data processing

Google Earth images of between 2003 and 2021 were acquired, georeferenced and subset using Ahero Town boundary shapefile as the AOI.

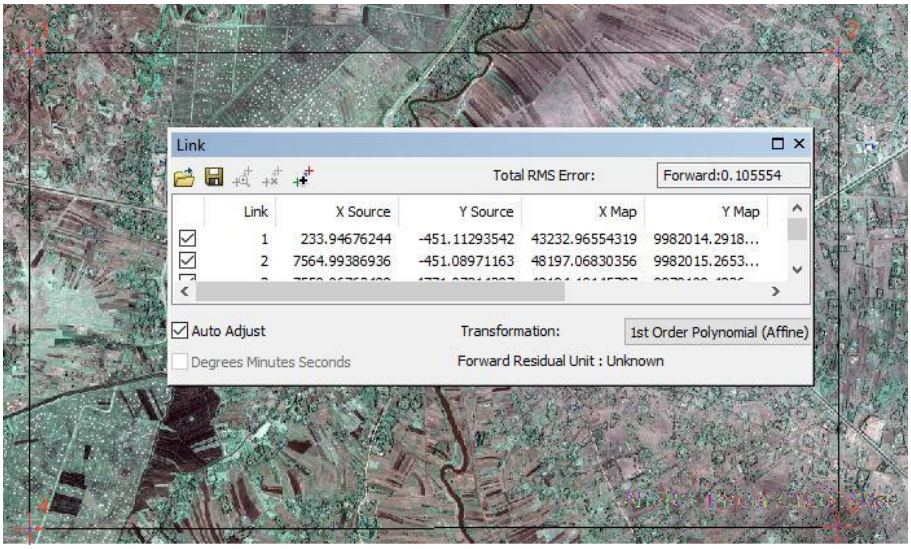

Figure 3.4: RMS error of georeferenced google earth image

3.4 Mapping Urbanization

3.4.1 Image Classification

Random Tree Classification was performed on the subsets by selecting the training sites evenly representing the five chosen classes within the image subset namely; Buildings, Water bodies Vegetation, Farmland, and, Bare land.

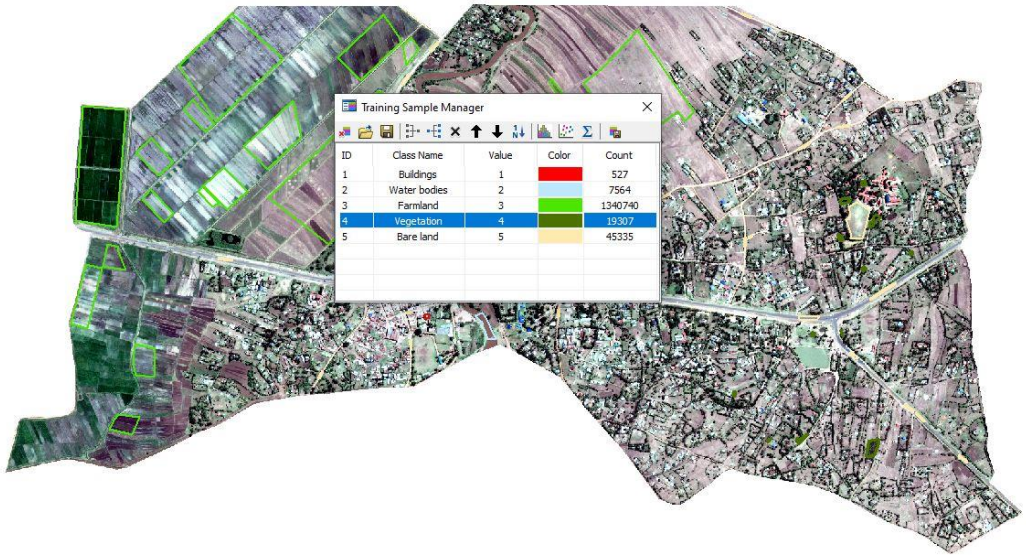

Figure 3.5: Training Sample Manager showing chosen classes.

For this study, Random Tree Classification method was chosen over other classification methods since the tool accepts multiband imagery with any bit depth, and it will perform the Random Trees classification on a pixel basis, based on the input training feature file.

An output classifier definition file (.ecd file) as shown in figure 3.6 was first created using the subset raster image and the training sample file. The .ecd file contains attribute information and statistics for the classifier.

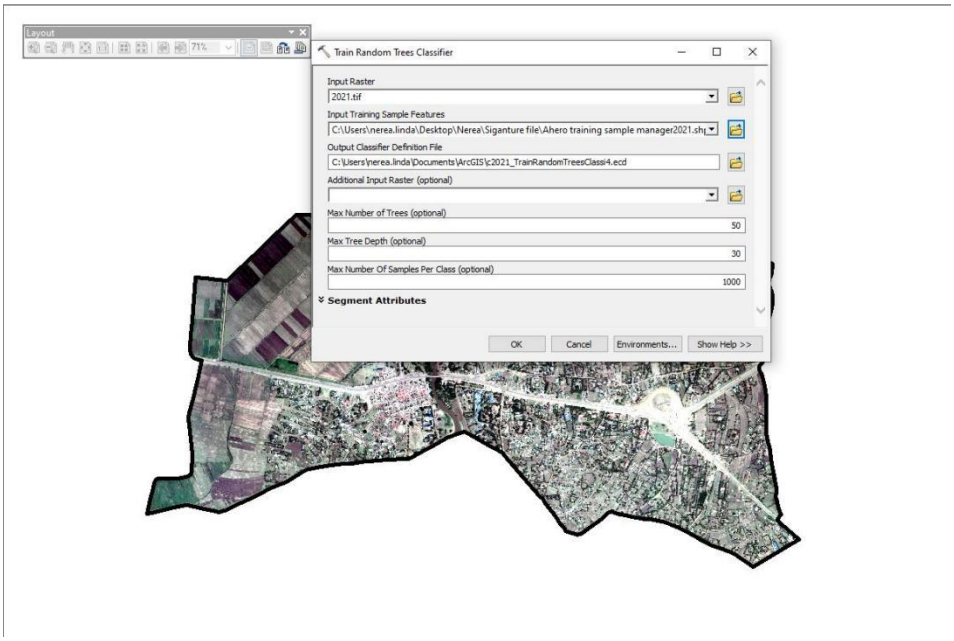

Figure 3.6: Creation of a class definition file.

Using the input .ecd file and the respective raster image, random tree classification was then performed to yield an output classified raster as shown in figure 3.7.

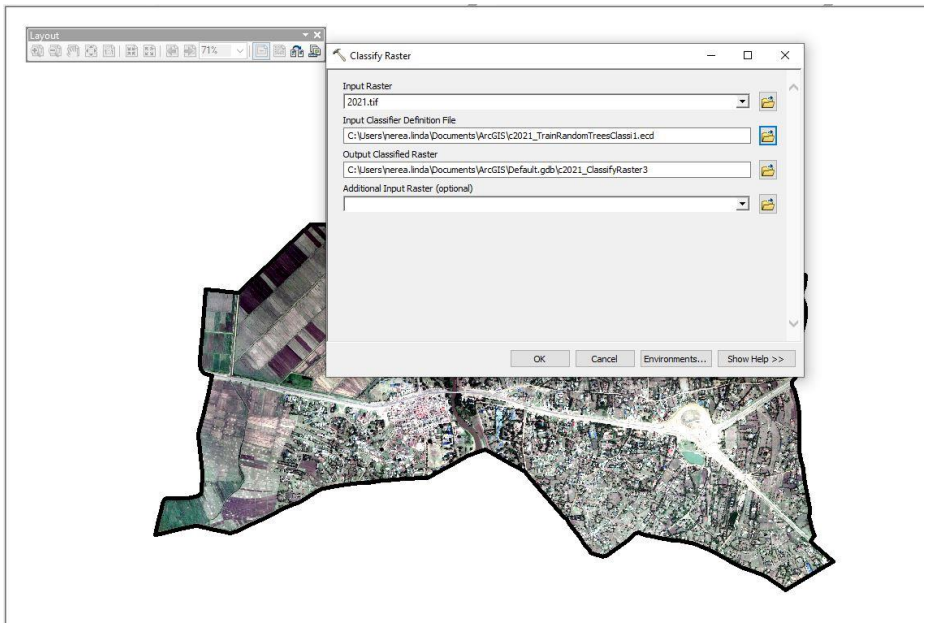

Figure 3.7: Random tree classification.

3.4.2 Accuracy Assessment

Confusion matrix was used for accuracy assessment on classification output to determine quality and confidence (Stehman & Foody, 2002).

3.4.3. Urban Change Detection

Change detection was done on Erdas.For a vivid change in land cover to be noticed, a matrix union, each of two different epochs was created.

3.5 Predicting Urban Growth

Prediction of 2030 land use land cover using TerrSet Geospatial Monitoring and Modeling System was carried out. Euclidian distance from roads and Euclidian and distance from rivers were generated using ArcGIS. These two, in addition to a 30meter Digital Elevation Model were used as inputs in generating the prediction map on TerrSet. The CA-Markov chain method in TerrSet was applied based on the past trends of the land use changes from 2003 to 2009 for the first scenario and from 2015 to 2021 for the second scenario. Based on this model, predicted land use map for the year 2030 was generated.

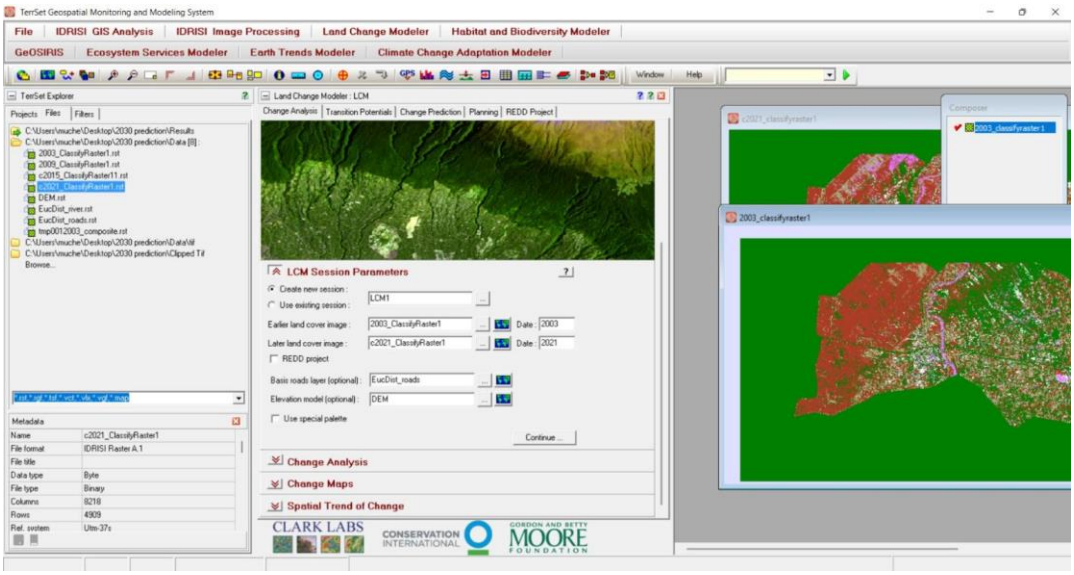

Figure 3.8: Prediction of 2030 LULC.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents detailed findings and analysis of the study. The land use/land cover maps resulting from the random tree classification clearly show changes in land use and land cover as depicted by figures 4.1 to 4.4.A prediction of the possible scenario of the town by 2030 is illustrated in figure 4.5.

Total area covered by the different land cover types is shown in table 4.1 and figure 4.6.

4.2 Land use and Land cover Maps

Figure 4.1 shows the land use/land cover for Ahero Town for the year 2003

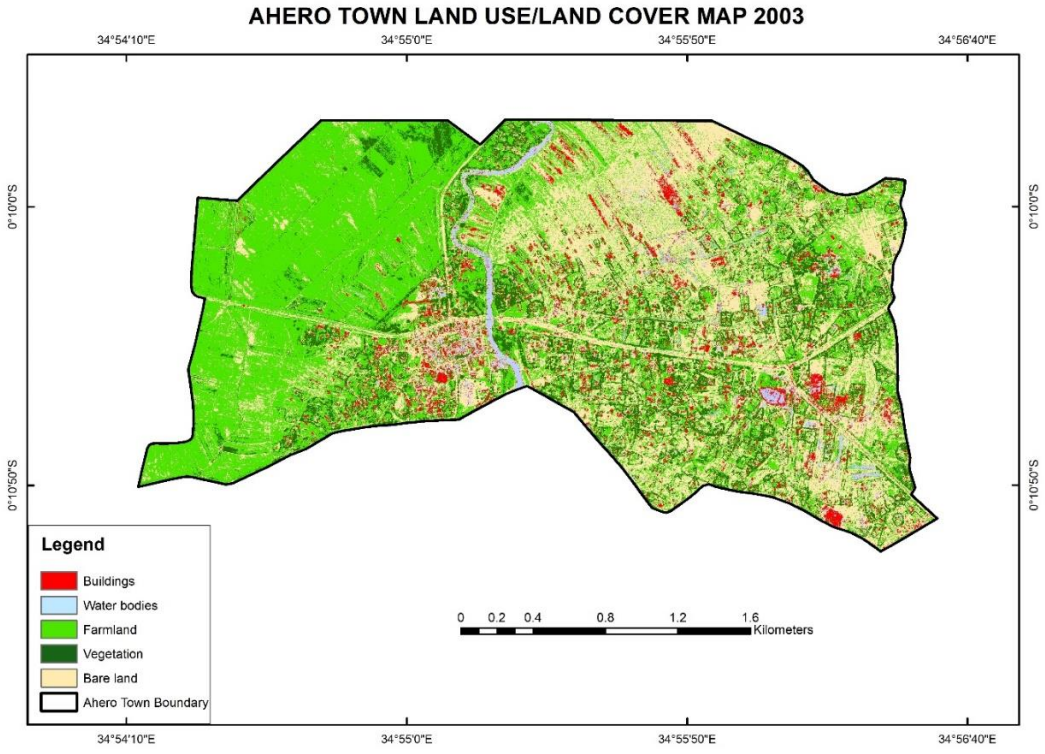

Figure 4.1: Ahero Town Land Use/ Land Cover Map 2003

Farmland is dominantly to the west of Ahero Town. Buildings are sparsely distributed around the town and there exists large portions of bare land towards the north eastern side of Ahero.

Figure 4.2 shows the land use/land cover for Ahero Town for the year 2009

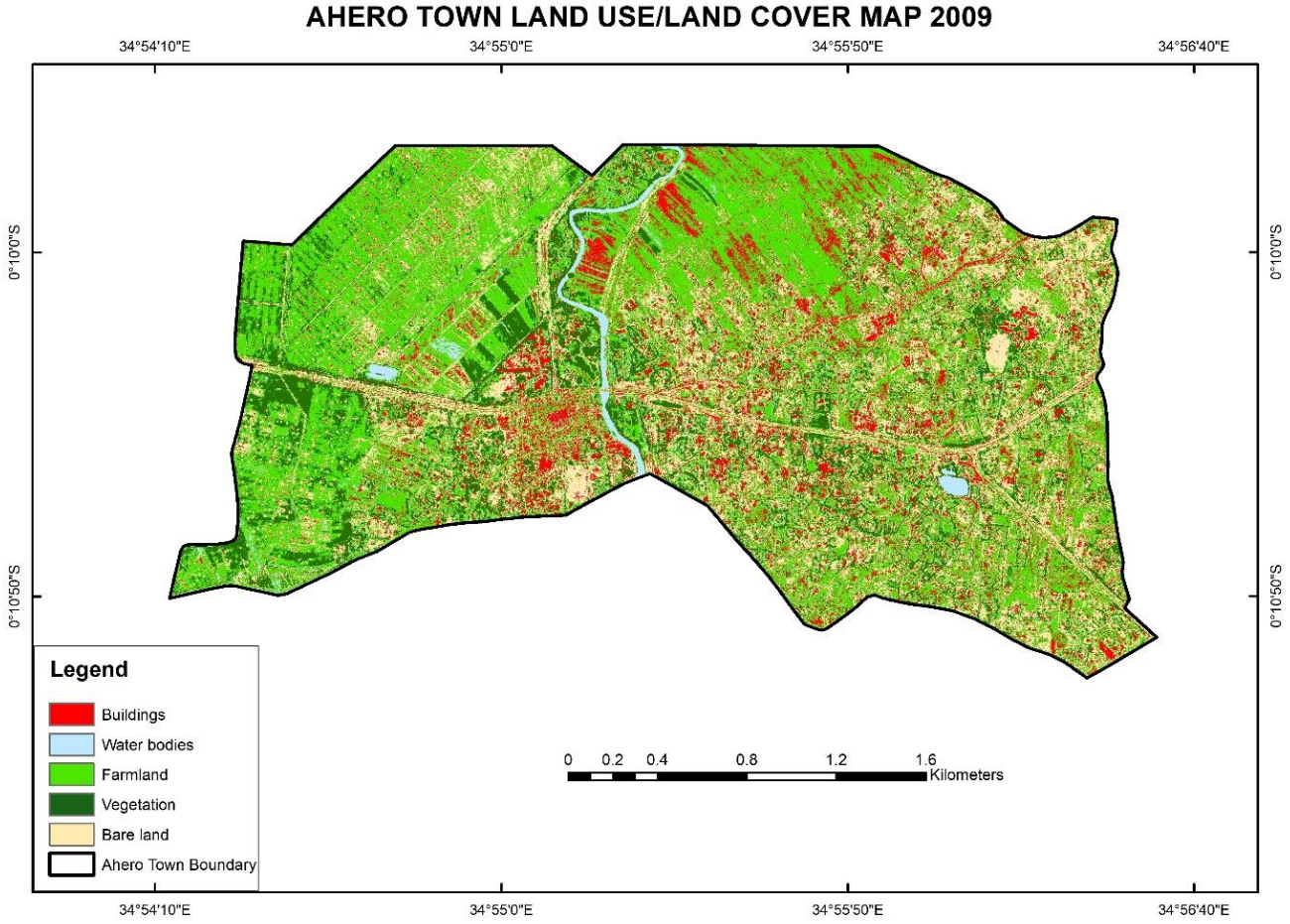

Figure 4.2: Ahero Town Land Use/ Land Cover Map 2009

There is notable reduction in the bare land, which translates to an increase in buildings around the town. There is also a slight increase in vegetation to the west of Ahero Town.

Figure 4.3 shows the land use/land cover for Ahero Town for the year 2015

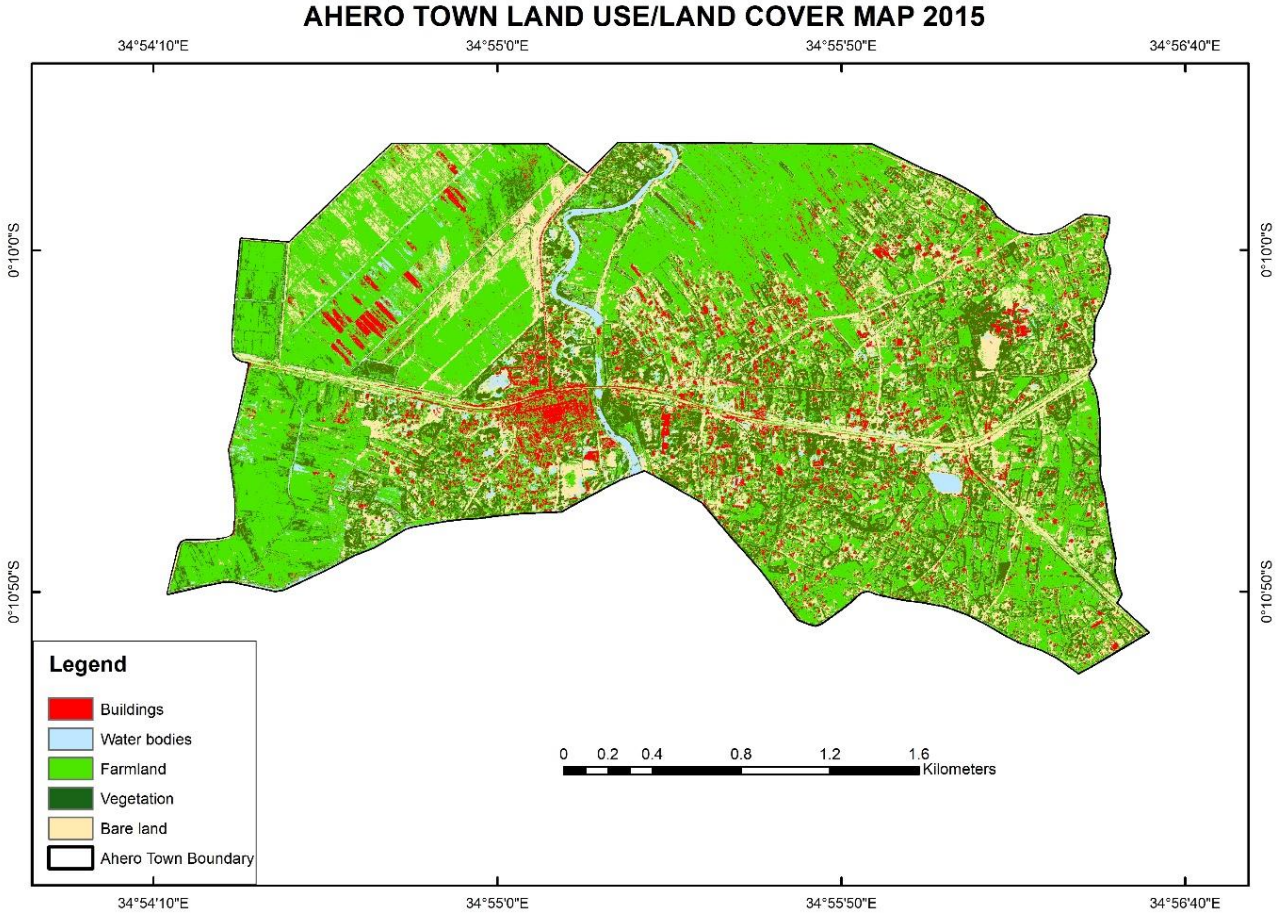

Figure 4.3: Ahero Town Land Use/ Land Cover Map 2015

There is dense settlement within Ahero Town. This is as a result of county governments which saw increased migration to Kisumu City and subsequently Ahero, since it is a satellite town. Bare land therefore reduced. Vegetation also reduced whereas Farmland and water bodies remained the same.

Figure 4.4 shows the land use/land cover for Ahero Town for the year 2021

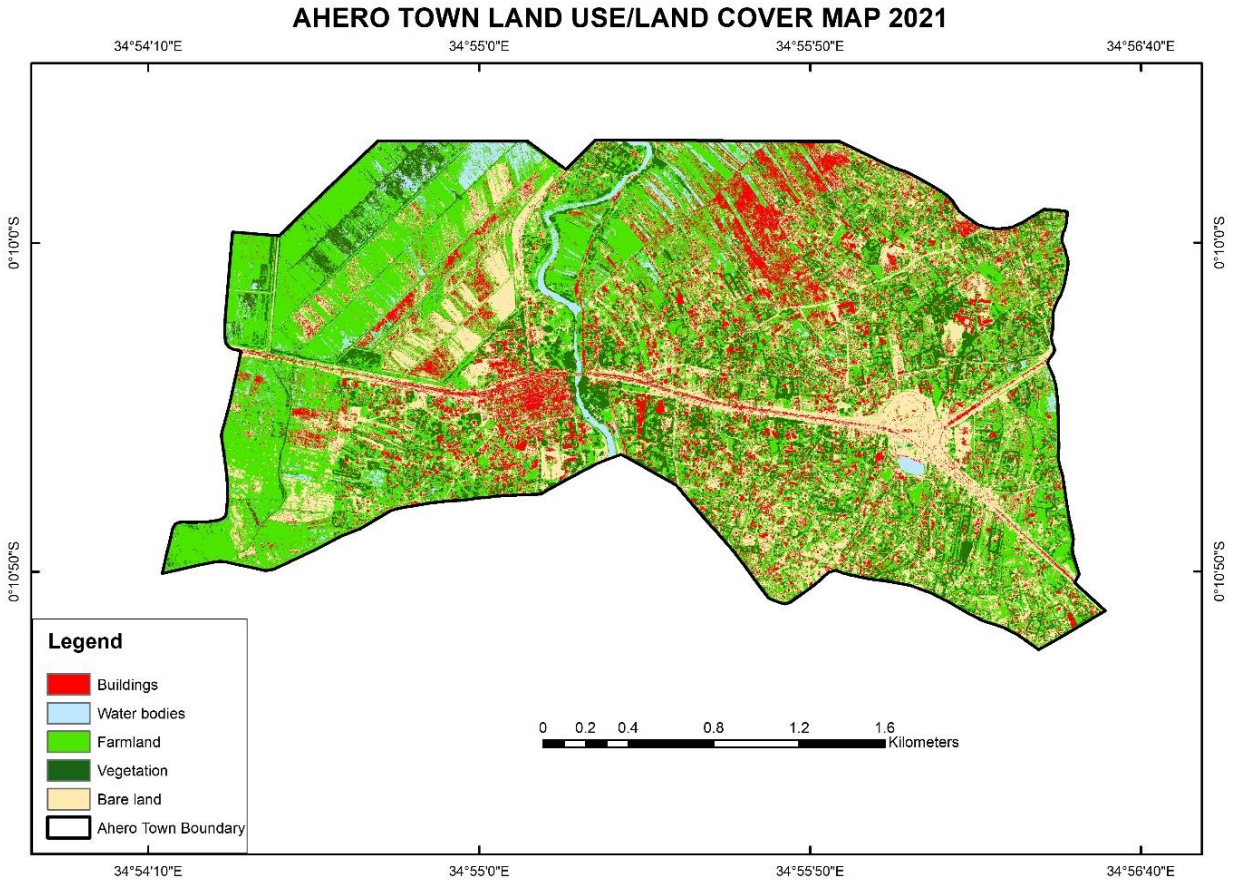

Figure 4.4: Ahero Town Land Use/ Land Cover Map 2021

The year 2021 saw a decline in farmland and vegetation. Bare land also decreased as a result of increase in buildings. Water bodies remained relatively the same.

Figure 4.5 shows the land use/land cover prediction for Ahero Town for the year 2030

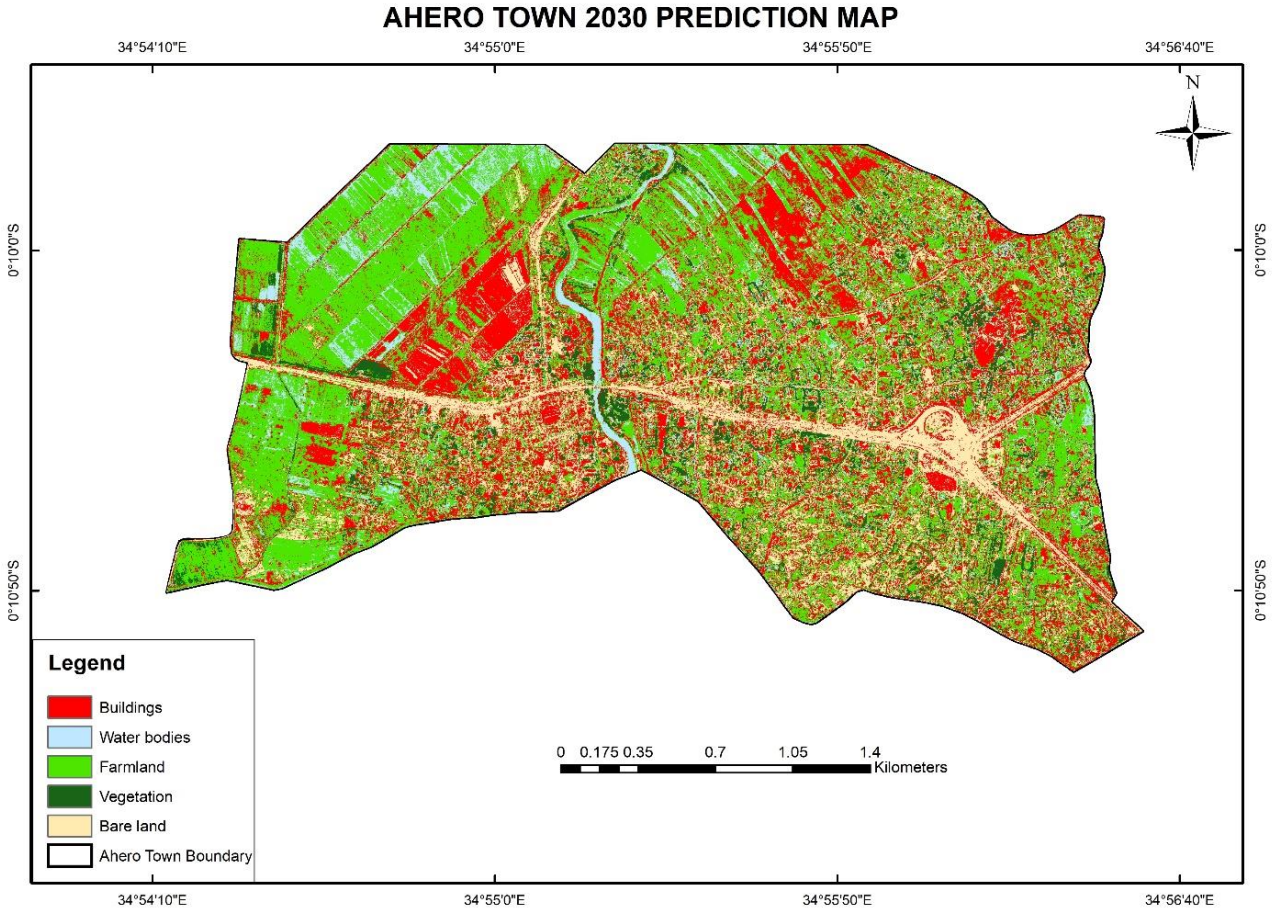

Figure 4.5: Ahero Town 2030 Prediction Map

There is a sharp increase in buildings expected by 2030, if the demonstrated trend continues. Buildings will be evenly spread throughout Ahero Town. This will result in a decline in bare land, farmland and vegetation.

4.3 Change Detection using Areas

From the analysis carried out, it is evident that there has been notable urban growth within Ahero Town since 2003. This is depicted by the increase in buildings.For instance, there has been a steady increase in buildings over the years, which has led to a decrease in bare land and vegetation. Water bodies and farmland have remained relatively the same over the years as shown in Table 4.1 and Figure 4.6 below.

Table 4.1: Total Area covered by land cover types for different epochs

Land Cover Type	Area in Hectares				
	2003	**2009**	**2015**	**2021**	**2030**
Buildings	39.01	50.58	83.65	101.94	157.52
Water bodies	23.72	24.31	24.22	24.28	27.69
Farmland	302.15	300.26	299.07	290.47	283.51
Vegetation	95.63	109.58	127.63	101.75	96.43
Bare land	239.03	189.34	164.97	148.38	134.39

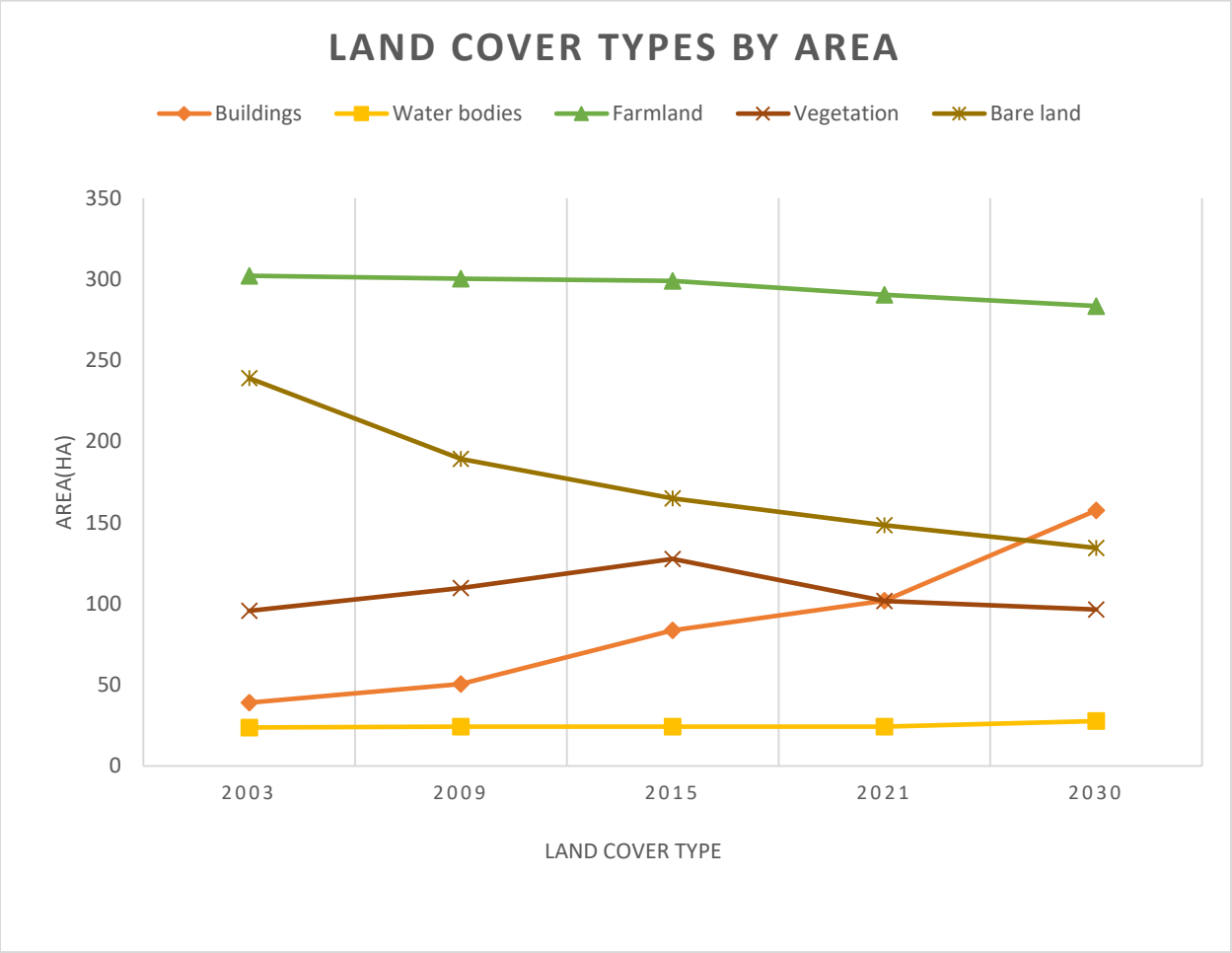

Figure 4.6: Total Area covered by land cover types for different epochs

4.4 Accuracy Assessment

Accuracy assessment for land use/land cover classification results was carried out for the three epochs,2003, 2009,2015 and 2021 and the reference data used were ground observations collected using a hand held GPS receiver. ArcGIS auto generated the assessment reports showing overall accuracy totals and overall kappa statistics for the different years, as illustrated in Table 4.2 below;

Table 4.2: Accuracy Assessment Results

YEAR	2003	2009	2015	2021
Overall Classification Accuracy (%)	84.62	88.46	79.31	82.58
Overall Kappa Statistics	0.7684	0.8443	0.7000	0.7216

The overall classification accuracy for the three epochs was above 75% which is the minimum threshold for any accuracy assessment. This showed that the results obtained had a high degree of accuracy, representing the real situation on the ground, and could thus be used to make informed decisions.

The overall kappa statistics was also within the required range, hence showing high correlation between ground observations data and classification results.

4.5 Discussion of the results

The results obtained give a clear indication that urban growth in Ahero Town has occurred majorly through existence of the Nairobi-Kisumu Road. Other roads like Kericho-Kisumu, Kisii-Kisumu and Ahero-Miwani roads have also influenced urban growth. This has contributed to the linear growth pattern witnessed.

Much development and urban set up came after the inception of the county governments under the new constitution 2010 through devolution, which made Ahero town grow rapidly as a result of population pressure in Kisumu City.

Increase in land market prices within Kisumu City has forced people to buy and develop land in the nearby areas such as Ahero, where they can still access city centre easily. This increase, coupled with low financial and economic potential resulted in subdivision of land into small portions which people can afford for commercial and residential use.

Preference of a quiet and peaceful environment outside Kisumu City has also played a major role in the growth of Ahero Town.

There exists serious land use conflicts and urban gaps within Ahero town centre and at the edges of the town due existence of informal settlements.

Rice farms within Ahero have also immensely contributed to the growth of the town. More and more people have migrated to the town in search of employment in the rice farms and milling plants.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, the aim of the study has been achieved. Remote sensing and GIS techniques have been successfully used to give a clear picture of the past, the present and possible future state of Ahero town. Just like most towns in the country, Ahero is one of the promising towns for the Kenyan economy especially because of the different activities that are involved, with rice farming being the leading source of income for most dwellers. In addition, hero is one of the satellite towns of Kisumu City, and thus is expected to experience rapid growth due to population growth within Kisumu, occasioned by establishment of the county governments.

The main waterbody within the town, River Nyando, has experienced negligible change over time. This is a positive indication of observance of the riparian reserve along the river. Vegetation has experienced fluctuation whereas farmland has undergone a slight reduction in areas covered by rice fields. The major growth indicator has been the steady increase in buildings, which has resulted in reduction of bare land within the town.

Uncontrolled urban development and lack of a spatial plan for Ahero Town has contributed to challenges such as increased pollution from both the liquid and solid waste, poor drainage and floods as well as urban sprawl into public land and along the highway.

Moreover, the authorities have been slow in adoption of new scientific techniques such as GIS and Remote Sensing in both the government and private sector. As a result, this has inhibited the planning and controlling of development within Ahero town.

5.2 Recommendations

To resolve the existing challenges and also to ensure that the future of Ahero town is set for controlled growth and improvement, this study recommends the following;

Adoption of geospatial techniques that would enable the local government in monitoring, managing and addressing the urban growth that is experienced in the town. Buffer zones need to be created for both natural and protected areas.

Creation of awareness on the use of Remote sensing techniques in the monitoring of urban growth, thus ensuring proper management of the town. County personnel, agencies and any other relevant individuals should receive training on the use of such tools and techniques.

Revamping of the GIS section in the planning department of Kisumu County would also go a long way towards ensuring that proper systems and databases are put in place, thus improving the decision making process in the development of Ahero Town.

Collaboration between national government and the county government in funding projects within the town that would improve the growth pattern as well as minimize uncontrolled development and pollution.

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