IMPACT OF LAND USE CHANGES ON MIGRATORY WILDEBEESTS AND ZEBRAS IN KITENGELA CONSERVATION AREA, KENYA

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DECLARATION

Declaration by the candidate

This thesis is my original work, and to the best of my knowledge, it has never been presented for a degree in any University. No part of this thesis may be produced without prior permission of the author and/or University of Eldoret.

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Approval by supervisors

This thesis has been submitted for examination with our approval as university supervisors.

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DEDICATION

This work is dedicated to my beloved mother, Lucy Ouma, who has been there for me and has supported me in all situations I have been through. I also dedicate this work to my wife, Madam Betty, who is God's most precious gift to me, and all wildlife lovers who dedicate most of their time to wildlife conservation.

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ABSTRACT

Wildlife migratory corridors and dispersal areas play a critical role in maintaining the ecological integrity of protected areas. However, increasing land use changes pose serious threats to these vital ecosystems. This study investigated the impacts of land use changes on migratory wildebeest (*Connochaetes taurinus*) and zebra (*Equus quagga)* in the Kitengela migratory corridor and dispersal area adjacent to Nairobi National Park. The study aimed to analyse the extent and trends of land use changes between 1988 and 2020; evaluate the relationship between migratory wild ungulate population trends and the increase in human population and changes in land use; determine the major drivers of these changes; and assess the impacts of land use changes on habitat, mortality, and behaviour of migratory wild ungulate populations in the area. The research utilised a mixed-methods approach, combining satellite imagery analysis, human population census data, wildlife population counts, direct observations, household interviews, and conversations with selected community members. A total of 110 households were surveyed using structured questionnaires to assess perceptions of land use changes in the area. Land use classification based on Landsat imagery for 1988 and 2020 revealed that approximately 61.4% of Kitengela's natural habitats were converted to bare land, cultivated land, and artificial surfaces, primarily driven by urban expansion, industrialisation, and agriculture. Changes in land use and rapid human population increase were associated with reduced migratory ungulate numbers, survival, and movement in and out of Nairobi National Park. The results also showed that migratory ungulates exhibit strong dependence on grassland and riverine habitats and show negative associations with cultivated, bare, and artificial surfaces, underscoring the ecological consequences of land transformation. Major drivers of land use changes included rapid human population growth (90%), agricultural intensification (51.8%), urbanisation (39.1%), changes in land tenure systems (15.5%), economic factors (8.2%), climate change (4.5%), fire (3.6%), and resource extraction activities (1.8%). Analysis of migratory wild ungulate populations showed significant population declines over the three-decade period, with habitat fragmentation emerging as the leading impact factor (91.8%). Land subdivision, fencing, and infrastructure development were identified as key barriers disrupting traditional migration routes and reducing habitat connectivity. The study recommends integrated land use planning, community-based wildlife corridor conservation, and habitat connectivity restoration to safeguard migratory ungulate populations in this rapidly urbanizing landscape. Further research should assess the long-term ecological effects of fragmentation, impacts of large-scale farming, and linkages between land use changes and climate variability in the Kitengela landscape.

Keywords: Land Use Change, Migratory Ungulates, Wildebeest, Zebra, Habitat, Kitengela, Nairobi National Park.

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LIST OF ACRONYMS

CBOs	Community Based Organisations
EAWLS	East African Wildlife Society
EIA	Environmental Impact Assessment
FoNNAP	Friends of Nairobi National Park
GIS	Geographical Information System
GOK	Government of Kenya
GPS	Global Positioning System
KM²	Square Kilometres
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
LANDSAT	Earth Observation Satellite
LUC	Land Use Change
MA	Millennium Ecosystem Assessment Framework
NGOs	Non-Governmental Organisations
NNP	Nairobi National Park
OLI	Operational Land Imager
QGIS	Quantum Geographical Information System
RCMRD	Regional Centre for Mapping of Resources for Development
ROI	Region of Interest
SPSS	Statistical Package for Social Sciences
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

DEFINITION OF TERMS

Anthropogenic Activities: These are actions taken by humans, like farming and construction, that change the natural habitats in Kitengela.

Behavioural Modification: This describes how the movement or habits of wild ungulates can change in response to human disturbances.

Conservation Area: These are landscapes outside of protected parks that play a vital role in supporting wildlife migration and dispersal.

Development: This refers to a process that creates progress or physical change in an environment.

Driver: This refers to any natural or human-induced factor that directly or indirectly causes a change in an ecosystem.

Geographic Information System (GIS): A powerful tool that helps map and analyse spatial data related to land use and the movement of wildlife.

Ground Truthing: This process involves verifying the classifications made from satellite images by checking them in the field.

Habitat Fragmentation: This happens when continuous habitats are split into smaller sections due to roads, fences, or other developments, which can hinder wildlife movement.

Habitat Loss: This is the permanent loss of natural habitats due to human development activities.

Human population increase: Refers to an increase in the number of persons living in a particular area.

Kappa Coefficient: A metric that assesses the accuracy of classifications by comparing satellite data with actual field observations.

Kitengela Conservation Area: refers to Nairobi National Park, Kitengela dispersal area, and migratory corridor.

Land Use Change: This refers to how human activities such as farming, urban development, and settlement are transforming the landscape in Kitengela, as evidenced by satellite imagery.

Land use: Refers to the utilization of land to improve the livelihood of individuals.

Migration Corridor: These are the routes that ungulates use to travel between different habitats, which can often be disrupted by development.

Migratory Wild Ungulates: These are hoofed mammals, such as wildebeest and zebras, that travel seasonally between Nairobi National Park and Kitengela in search of food and water.

Population Trend: This refers to the changes in the sizes of human and wildlife populations over time, which we can assess using statistical methods.

Remote Sensing: This technique involves using satellite images to monitor and analyse changes in land cover over time.

Spearman's Correlation Coefficient: A statistical tool used to measure the relationship between ranked variables, like comparing human populations to ungulate populations.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The growing human population is encroaching on protected areas and wildlife migratory routes like never before (Katswera *et al.*, 2022). Over the last thousand years, human activities have dramatically changed about three-quarters of the Earth's land (Winkler *et al.*, 2021). Things like infrastructure development, shifts in land ownership, and changes in how people use land in areas where wildlife used to roam have had a huge impact on biodiversity, especially in conservation zones (Lerman *et al.*, 2023). These issues are made worse by human actions such as privatizing land, farming, building roads, putting up fences, expanding settlements, and raising livestock, all of which threaten many wildlife species (Büscher, 2021).

Changes in land use are a major factor driving the ongoing biodiversity crisis and the significant shifts happening in terrestrial ecosystems, leading to a widespread loss and degradation of wildlife habitats around the world (Palombo, 2021). The way landscapes change is closely tied to the livelihoods of local communities and their views on conserving biodiversity, which in turn affects the ecological sustainability of these regions (Oldekop *et al*., 2020). These processes are constantly evolving over time and space, influenced by a mix of biological, physical, and socioeconomic factors (Alberti *et al.*, 2020). In the last 300 years, the effects of land use change have reached alarming levels, primarily due to human activities (Liu *et al.*, 2020). As our population keeps growing, ecosystems like forests and grasslands are steadily declining (Hobohm *et al.,* 2021).

Wildlife dispersal areas and migratory corridors are essential for minimizing the risk of local extinctions by allowing wildlife to move freely (Hilty *et al.,* 2020). These pathways help animals travel between different habitats in search of food, water, shelter, breeding grounds, and other vital resources (Kageni, 2018). Without access to these dispersal areas, protected populations can suffer from genetic drift and inbreeding, which can destabilize their numbers, compromise ecological health, and even lead to local extinctions (Robinson *et al.*, 2023). In Kenya, while wildlife is safeguarded within national parks, reserves, and conservancies, over 70% of wildlife roams outside these protected zones, occupying privately and communally owned lands (Otianga-Owiti *et al.*, 2021). Unfortunately, most of the benefits that come from wildlife are directed to the central government (Comer *et al*., 2025).

Dispersal areas are crucial for allowing wildlife to move beyond protected regions (Katswera *et al.*, 2022). For instance, Kitengela is key for enabling wildlife to migrate from Nairobi National Park (NNP) (Otiego, 2024). Recognizing its importance for the sustainability of NNP, the Kitengela Plains were designated as a conservation area to protect migratory wildlife. However, this designation was not gazetted as a conservation area, leaving the area without any land use restrictions (Katswera *et al.*, 2022). Activities such as land fencing, settlement expansion, farming, and infrastructure development have drastically reduced the land available for wildlife (Kariuki *et al.,* 2021). Consequently, the survival of wildlife in the park heavily depends on the willingness of private landowners in the Kitengela dispersal area to allow wildlife to move across their properties (Kibet, 2024). For the park to keep its ecological balance, private landowners must work together by keeping their lands open for migration of wild ungulates in the area (Middleton *et al*., 2022).

Historically, the Kitengela plains formed part of the Athi–Kapiti rangelands traditionally occupied by the Maasai pastoral community, where land was used communally for livestock grazing and seasonal movements (Kariuki *et al.*, 2021). Settlements were temporary and scattered because the Maasai practiced nomadic and semi-nomadic pastoralism, allowing wildlife to move freely between the plains and Nairobi National Park (Sundstrom, 2009).

In the 1960s and 1970s, the government introduced the group ranch system to formalise communal land ownership in Maasai areas, improve rangeland and livestock management, and facilitate socio-economic development while maintaining open landscapes for pastoralism and wildlife dispersal from Nairobi National Park (Nkedianye et al., 2009). Under this arrangement, communal land was demarcated into large ranch units held under collective ownership by Maasai members. However, beginning in the mid-1980s, many of these group ranches in the Kitengela-Athi Kapiti plains were subdivided into individually owned parcels, and members were issued title deeds (Wandaka & Francis, 2019). This process encouraged permanent settlement and enabled landowners to sell or lease land. Consequently, many plots were purchased by immigrants and investors, increasing settlement and land fragmentation (Nyaila, 2021).

The rapid urbanization of Nairobi city further accelerated settlement in Kitengela dispersal area (Odongo & Donghui, 2021). Due to its proximity to the city, the area became attractive for residential development, business opportunities, and infrastructure expansion. As a result, Kitengela gradually transformed into a peri-urban commuter town, leading to increased housing developments, agriculture, and infrastructure (Araka, 2021). These changes have significantly altered land use patterns, contributing to habitat fragmentation and reducing open rangelands that previously supported wildlife migration (Robinson *et al.*, 2023). These changes in land use have compromised the integrity of the corridor and dispersal area, leading to a decline in its primary productivity, a drop in wildlife diversity, and a shrinking of the migratory corridor (Song *et al.*, 2024).

Additionally, large-scale irrigated horticultural projects and quarrying operations have sprung up since the land privatisation (Nyaila, 2021). If these current land use trends continue without intervention, Kenya could face a significant loss of migratory wildlife, threatening its genetic biodiversity.

1.2 Problem Statement

Rapid land use changes in Kitengela Conservation Area are increasingly affecting wildlife conservation and management in Nairobi National Park. Although the park is a protected area, many wildlife species depend on surrounding dispersal areas such as the Kitengela plains for grazing, breeding, and seasonal migration. However, population growth, land subdivision, urban expansion, and infrastructure development in Kitengela have accelerated in recent years, leading to habitat fragmentation and obstruction of traditional wildlife migratory routes (Ogembo *et al.,* 2022; Araka, 2021).

These land use changes have resulted in increased fencing, settlement expansion, and road development, which restrict wildlife movement and increase risks such as wildlife mortality, habitat degradation, and behavioural changes among species (Banks-Leite et al., 2020; Barrientos *et al.,* 2021; Schell *et al.,* 2021). As a result, the ecological connectivity between Nairobi National Park and surrounding dispersal areas is increasingly threatened, potentially leading to declines in wildlife populations and biodiversity (Bănăduc *et al.,* 2022). The Kitengela ecosystem acts as a crucial wildlife corridor, facilitating seasonal migrations and helping animals adapt to changing climate conditions (Katswera *et al.*, 2022). These corridors are essential landscape features that connect protected areas to surrounding regions where wildlife can disperse (Hofmann *et al.*, 2021). In this regard, the Kitengela wildlife corridor links NNP to areas like the Athi-Kapiti plains, which serve as a vital breeding ground for migratory species such as wildebeests (Gichuru, 2022) (Figure 1.1).

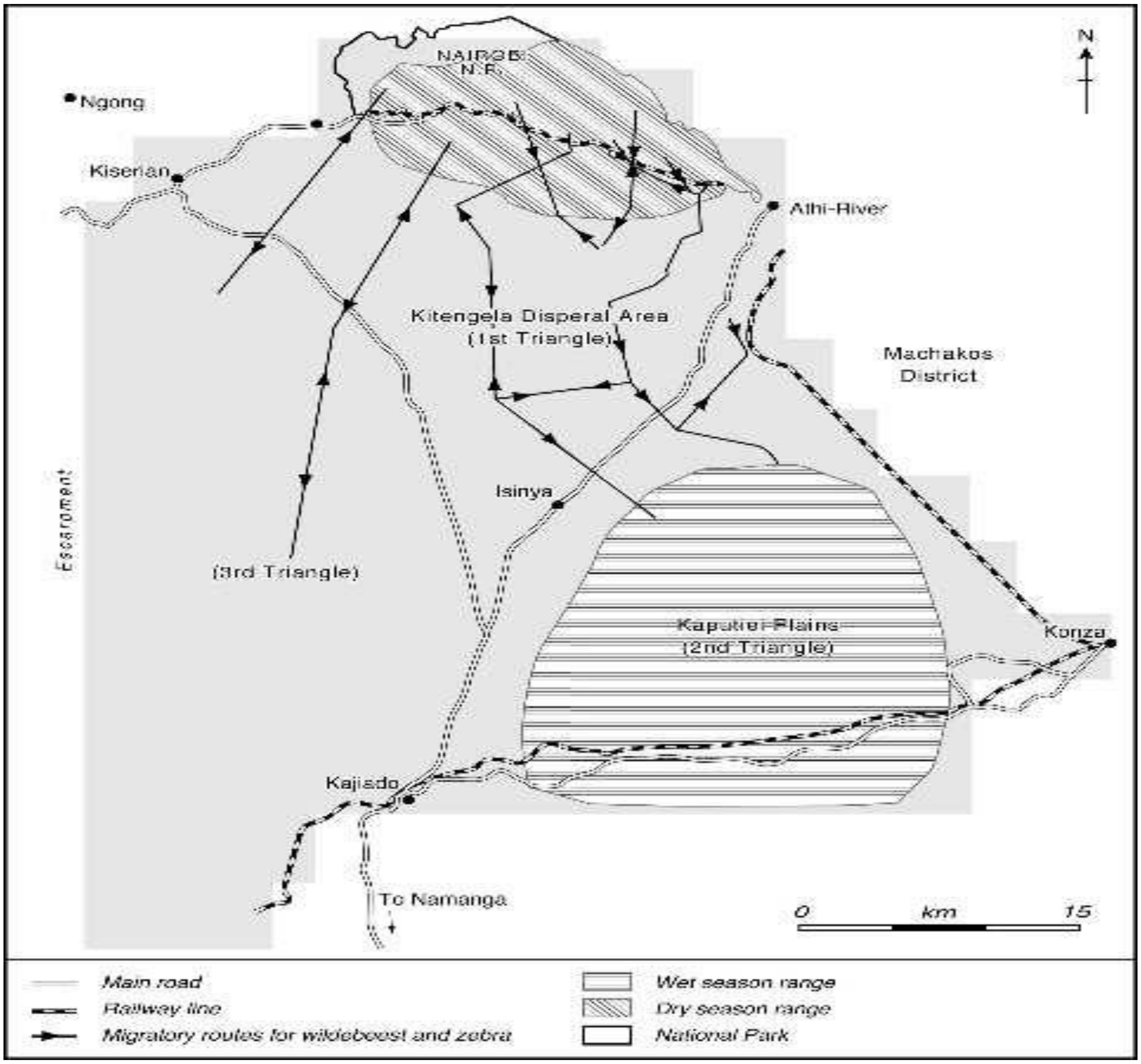

Figure 1.1 Map showing the extent of the Kitengela wildlife corridor

Source: Nkedianye *et al.* 2009

Despite the ecological importance of the Kitengela wildlife corridor in supporting migratory species and maintaining ecosystem balance, limited attention has been given to understanding the extent to which changing land use patterns affect wildlife movement and conservation. Therefore, this study seeks to assess the impacts of land use changes in the area and provide information that can support sustainable land management and effective wildlife conservation in Nairobi National Park and its surrounding ecosystems.

1.3 Research Objectives

1.3.1 Main Objective

To investigate the impacts of land use changes in the Kitengela conservation area on the wild ungulate population in Nairobi National Park.

1.3.2 Specific Objectives

(i) To analyze the extent and trends of land use changes that have occurred in the Kitengela conservation area between 1988 and 2020.

(ii) To evaluate the relationship between trends in migratory wild ungulate populations and both human population dynamics and land use changes in Kitengela Conservation Area.

(iii) To examine the driving factors behind land use changes in the Kitengela conservation area.

(iv) To assess the impacts of land use changes on mortality, behaviour, and habitat of migratory wild ungulates in the Kitengela conservation area.

1.4 Research Hypotheses

H_{01}: Expansion of artificial surfaces, agricultural land and human population growth in Kitengela are positively correlated with the population of migratory wild ungulates in the Kitengela conservation area.

H_{02}: All perceived drivers of land use change in Kitengela are reported with equal frequency by respondents.

H_{03}: Socio-demographic factors (such as age, gender, education level, occupation, and years lived in the area) do not significantly affect how respondents perceive the impacts of land use changes on wild ungulates.

1.5 Justification of the Study

This study was justified by the growing pressure on the Kitengela dispersal area, which has historically supported the coexistence of wildlife, livestock, and human communities but is now undergoing rapid transformation due to population growth, land subdivision, and changing land use practices (Gichuru, 2022; Nath *et al.*, 2020). Because the area continues to serve as an important calving and grazing ground for migratory wildlife during the wet season, any disruption to land accessibility directly threatens the survival of species that depend on movement between Nairobi National Park (NNP) and the surrounding plains (Nkedianye *et al.*, 2020; Kibet, 2024).

The study was also necessary because, although the Kitengela plains are widely recognised as vital to the ecological sustainability of NNP, they remain largely privately owned and lack formal land use restrictions. This creates a conservation gap in which wildlife persistence depends heavily on the willingness of individual landowners to maintain open space for movement and seasonal dispersal (Gichuru, 2022; Nkedianye *et al*., 2020; Katswera *et al.,* 2022). In such a setting, research-based evidence is essential to demonstrate the ecological consequences of unregulated land conversion and to support more effective conservation planning.

In addition, the study was justified by the increasing threats already documented in the ecosystem, including human-wildlife conflict, settlement expansion, farming, fencing, and infrastructure development, all of which interfere with migratory routes and habitat connectivity (Otianga-Owiti *et al*., 2021). Since the Kitengela conservation area supports one of the largest migratory wildebeest and zebra populations in Kenya outside the Serengeti–Mara system, continued land transformation without adequate understanding poses serious risks not only to wildlife populations but also to the ecological functioning of NNP itself.

Finally, the study was justified by the need for localised and time-based evidence on how land use change and human population dynamics are affecting migratory wild ungulates in the Kitengela conservation area. Generating such evidence is important for informing sustainable land management, strengthening corridor protection, and guiding future policy interventions aimed at balancing conservation objectives with human livelihood needs in this rapidly changing landscape.

1.6 Significance of the Study

This study is significant because it addresses a critical conservation challenge in the Kitengela conservation area: the rapid loss of habitat connectivity caused by land use change in one of Kenya's most important wildlife dispersal areas. Previous studies have shown that wildlife migratory corridors and dispersal areas are essential for maintaining ecological balance, species movement, and long-term ecosystem health, especially for migratory ungulates that rely on seasonal access to feeding, calving, and refuge areas (Gatti, 2025; Middleton *et al.,* 2020). In the case of NNP, the Kitengela dispersal area plays a particularly important role in sustaining migratory wildlife populations and preserving the ecological functionality of the park (Mwangi *et al.,* 2022; Gichuru, 2022).

The study is also important because it provides empirical evidence on how land use changes, human population growth, and habitat fragmentation are influencing migratory wild ungulates over time. By linking long-term land use change analysis with wildlife population trends from 1988 to 2020, the research contributes context-specific knowledge needed to understand how urban expansion, agricultural intensification, fencing, and land subdivision are reshaping the NNP-Kitengela landscape and threatening wildlife movement and survival. This makes the study valuable not only for understanding ecological change but also for identifying the drivers of wildlife decline in a rapidly urbanising conservation area.

In practical terms, the findings of this study are significant for policy and management. They can inform land use planning, conservation zoning, habitat restoration, and the protection of wildlife corridors within the Kitengela ecosystem. The findings may also support awareness creation among local communities, planners, and conservation agencies by demonstrating the ecological consequences of unsustainable land conversion and the urgency of balancing development with biodiversity conservation (Gichuru, 2022).

Finally, this study is significant from an academic and research perspective because it adds to the growing body of literature on land use change, protected area connectivity, and migratory wildlife conservation in East Africa. It provides a useful reference point for researchers, students, conservation practitioners, and policymakers working in other ecosystems facing similar pressures from human settlement, infrastructure development, and fragmentation of wildlife habitats.

1.7 Assumptions of the Study

The study was based on several key assumptions:

i. Changes in land use within the Kitengela ecosystem threaten the long-term sustainability of Nairobi National Park, which in turn impacts the ecological health and well-being of the surrounding conservation area.
ii. Between 1988 and 2020, significant land use changes took place in the Kitengela conservation area, affecting wildlife habitats and migratory patterns. The sample chosen for the study accurately represented the target population, enabling the findings to be generalised.
iii. Respondents provided honest information that genuinely reflected their views and experiences regarding land use changes and conservation challenges.
iv. The accuracy assessment of the 2010 and 2020 land use maps was adequate to determine the reliability of the classified maps from 1988 and 2000, thanks to the consistent methods and classification techniques used.

1.8 Scope of the Study

This study aimed to assess the impacts of land use changes in the Kitengela conservation area on migratory wild ungulates in Nairobi National Park. The research was carried out in both NNP and the Kitengela dispersal area, reaching up to 22 kilometres south of the park's boundary. Land use data were gathered from Landsat satellite images, tracking changes from 1988 to 2020. The study specifically looked at how these land use changes have affected wildlife habitats, particularly vegetation and water sources.

Additionally, the study examined land use changes and human population dynamics and their relationship with wild ungulate populations in NNP over the same timeframe. Data on the factors driving land use changes and other conservation-related issues were collected through questionnaires distributed to households within the Kitengela ecosystem, as well as through interviews with staff from Kenya Wildlife Services (KWS) and various Non-Governmental Organisations (NGOs) active in the area.

1.9 Limitations of the Study

A limitation was the aggregation of diverse built-up land uses into a single 'artificial surfaces' class due to the spatial resolution of the imagery, preventing distinction of finer categories such as commercial, residential, or industrial uses.

Because of limited transportation access, land use change data were collected using GPS in only areas that were reachable by road. In addition, I faced a significant hurdle in obtaining the Landsat satellite image for 1990. Consequently, I had to use the Landsat image from 1988 as a substitute for that year.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept of Migratory Wildlife Corridors and Their Role in Wildlife Conservation

Wildlife migratory corridors, often called habitat corridors, are vital areas that link wildlife populations cut off by human activities like roads, urban sprawl, and farming (Gichuru, 2022). These corridors act as designated paths that migratory animals use during their seasonal journeys or as routes for relocating between different habitats (Merkle *et al.*, 2022; Prasad, 2024). You can find various types of wildlife migratory corridors, including terrestrial, aquatic, aerial, and transboundary corridors (Katswera *et al., 2022)*.

On the other hand, wildlife dispersal areas cover larger regions where animals roam for reasons beyond just migration, such as breeding, foraging, and establishing territories (Newton, 2023). These dispersal movements are essential for maintaining gene flow, which in turn affects individual fitness, population dynamics, genetic diversity, and the distribution of species (Hilty *et al.*, 2020b). Well-maintained corridors allow migratory wildlife to move between protected areas, helping them escape harsh conditions, find mates, and ultimately support genetic diversity (Bollig, 2024). Landscape connectivity is the extent to which a landscape allows or hinders movement between habitat patches and is crucial for maintaining ecological health (Mony *et al*., 2022). Unfortunately, changes in land use are increasingly disrupting this connectivity, making it harder for wildlife to navigate these essential corridors (Prasad, 2024).

A study by Anh & Mai (2024) highlights the vital role that wildlife migratory corridors play in linking core habitats, which is essential for the survival and long-term health of ecosystems. Migration allows animals to reach crucial resources like food, water, and breeding sites, helps them avoid predators, and supports genetic diversity (Cooke *et al.*, 2024). Therefore, conserving connectivity is key to expanding the effective habitat available for biodiversity, especially in the face of habitat fragmentation and human-induced changes to the landscape (Yang *et al.*, 2025). Restoring and maintaining these wildlife corridors is crucial for enhancing ecosystem integrity and countering the negative impacts of fragmentation (Prasad, 2024).

Around the world, there are compelling examples that showcase the importance of wildlife corridors. For instance, the Manuel Antonio Wildlife Corridor in Costa Rica illustrates how biodiversity conservation can go hand in hand with local economic development, even when faced with significant challenges (Gutierrez, 2020). Likewise, Singapore's Eco-Link@BKE Bridge exemplifies innovative infrastructure designed to counter habitat fragmentation to ensure wildlife can move freely over urban infrastructure (Chan *et al.*, 2023).

In sub-Saharan Africa, many protected areas are becoming increasingly isolated within landscapes altered by human activity (Chiaka *et al.*, 2024; Gatwaza & Wang, 2023). However, the existence of wildlife corridors and dispersal areas surrounding these parks helps to ease the pressure. For example, Tarangire National Park in northern Tanzania has historically acted as a refuge during the dry season, with wildlife using nine different routes to access wet-season dispersal areas nearby (Lohay *et al.*, 2022). The Kwakuchinja Wildlife Corridor (KWC) connects Lake Manyara National Park to Tarangire, facilitating this essential movement of species such as elephants, lions, buffaloes, giraffes, warthogs, and zebras (Njamasi *et al.*, 2022).

In Kenya, the Mount Kenya Elephant Corridor Project is a shining example of how we can creatively restore connectivity for wildlife (Okita-Ouma *et al.*, 2021). It boasts Africa's very first elephant underpass, a remarkable 14-kilometre stretch that connects Mount Kenya National Park with the Ngare Ndare Forest Reserve. This corridor allows around 2,000 elephants to safely traverse between these habitats without causing human-wildlife conflicts (Katswera *et al.,* 2022). The underpass plays a crucial role in ensuring that these majestic creatures can cross busy highways without danger, protecting both the elephants and the local communities while also encouraging genetic diversity among elephant populations (Gibbon, 2021).

However, the rapid growth of human populations and changes in socioeconomic lifestyles pose serious challenges to wildlife conservation in rangelands across the globe (Simba *et al., 2024)*. Research in the Athi-Kapiti ecosystem has shown alarming habitat loss due to land development, which has had a detrimental effect on wildlife corridors (Wanjiku, 2023). In this scenario, the Kitengela ecosystem stands as the last remaining corridor, yet it is increasingly threatened by human encroachment and urban sprawl (Gichuru, 2022). The ongoing pressure on Kitengela's migratory routes jeopardizes the survival of wildlife populations in Nairobi National Park, underscoring the urgent need for effective conservation strategies and thoughtful land use planning (Kibii, 2020).

2.2 Land Use Changes and Their Impacts on Wild Ungulates

According to Ellis (2021), land use change refers to how human activities reshape our natural landscapes. They point out that these changes can involve biological, chemical, or physical shifts brought on by various management practices. This can mean anything from turning grazing land into cropland, tweaking fertiliser use, enhancing drainage systems, setting up irrigation, building structures like dams, and starting new plantations to dealing with land degradation and pollution. It also includes the lifting of regulations, the spread of invasive species, changes in fire management, and even converting land for non-agricultural purposes.

A study by Daniel (2024) highlighted a significant trend: cultivated lands are expanding, often at the cost of bushlands, grasslands, and forests. This shift has led to a notable decrease in areas that are still covered by natural vegetation (Vitasse *et al.*, 2021). Once land is converted from its natural state to grazing or farming, things get more complicated (Horton, 2020). This complexity grows due to intensification and diversification, especially as land becomes scarcer and farms shrink because of subdivision (Tadele, 2021). The Sobhani *et al*. (2021) study shows that these land use changes have caused habitat fragmentation, which in turn limits the habitats available for wildlife. As a result, wildlife movement and access to essential resources like water and grazing areas during dry seasons have been restricted, reducing their grazing range (Skovlin, 2021). The closer proximity of humans to wildlife has led to a drop in animal populations and a decrease in species diversity in the affected regions (Doherty *et al.,* 2021). Across all the study sites, a consistent decline in wildlife populations was noted.

A global study by Winkler *et al.* (2021) found that nearly a third of the Earth's land surface underwent significant changes between 1960 and 2019, much more than earlier long-term assessments had suggested. Their research highlights a varied pattern in land use: while the Global North saw more cropland abandonment and afforestation, the Global South experienced agricultural expansion and deforestation. The study also points out that the shift from relatively stable land use to a rapid increase in changes aligns with a transformation in global food systems, moving from agro-technological intensification to production aimed at global markets and a rise in international trade of commodity crops.

2.3 Human Population Increase and Land Use Change and Their Implications on Migratory Wild Ungulates

The growing human populations near wildlife migratory corridors are having a significant impact on biodiversity (Liu *et al.,* 2020). This is mainly due to the restrictions on species movement, habitat fragmentation, and an increase in human-wildlife conflicts (Elisa *et al.*, 2024). As more people settle in these areas, the demand for land rises, often leading to the encroachment on essential migration routes (Rehman & Khan, 2022). This issue can be seen in various regions around the world.

2.3.1 Global Relationship

A projected study shows that by 2050, land converted for agriculture, urban expansion, and energy infrastructure could cause a 5-16% decline in mammal habitat compared to 2015 levels, disproportionately impacting large-bodied species such as wild ungulates (Baisero *et al.*, 2020; Oladimeji, 2024). An extensive global analysis covering 27 migratory ungulate species recorded 127 migration disruption events, with human population density and habitat loss being key correlates of range contraction and migration impairment (Pacifici *et al*., 2020). In essence, as human populations grow and transform landscapes, ungulate populations suffer through reduced connectivity, increased mortality, and local declines (Berger *et al.*, 2020).

2.3.2 Relationships in Africa

In the Kavango-Zambezi (KAZA) area, Botswana, veterinary fencing intended for livestock disease control has fragmented wild ungulate habitats, and the fence assessment confirmed that these barriers critically block seasonal movements of species like wildebeest and zebra, leading to dehydration, entrapment, and intensified poaching pressure (Rosen *et al.*, 2024). Parallel elephant studies using GPS data reflect similar constraints: female elephants no longer cross these fences, fragmenting populations and limiting access to crucial seasonal resources (Naidoo, 2004). This illustrates the strong linkage between land use policy (agricultural fencing) and species decline in wild ungulates (Kariuki *et al.*, 2021).

2.3.3 Relationships in East Africa

A 2022 remote sensing study in Nakasongola District in Uganda revealed dramatic land cover changes between 1985 and 2021: farmland expanded from 7.2% to 35.8%, while grasslands shrank from 31.7% to 18.5% (Kuule *et al.*, 2022). Key drivers identified by both satellite data and local community perceptions include population growth, overgrazing, wood fuel extraction, and subsistence farming. These shifts have fragmented rangeland ecosystems and degraded forage availability negatively impacting the spatial distribution and population viability of wild ungulates in the region (Rumiano *et al*., 2020).

2.3.4 Relationships in Kenya

A comprehensive 2022 study mapped land use conversion and fencing across 30,000 km^2 of southern Kenyan rangelands, documenting nearly 40,000 km of new fences and conversion of 1,500 km^2 to agriculture (Tyrrell *et al*., 2022). This rapid subdivision and fencing have fragmented wildlife corridors used by wildebeest, zebra, and elephant, often overlapping with migratory paths. A 2024 genetics-focused investigation revealed that wildebeest populations isolated by these barriers show significant genetic bottlenecks and reduced gene flow (Turner *et al.*, 2022), further evidence of population-level impacts.

2.4 Drivers of Land Use Changes

Changes in land use around protected areas can stem from natural events like volcanic eruptions, climate changes, and alterations in sea levels or river paths (Gordon *et al*., 2022). However, in recent years, most of these changes have been driven by human activities, especially the growth of agricultural production and urban development (Güneralp *et al.*, 2020), largely spurred by the increasing global population. These trends underscore the intricate relationship between human actions, natural systems, and conservation goals (Ali & Kamraju, 2023).

2.4.1 Global Drivers of Land Use Change

Industrial-scale agricultural expansion remains the largest driver of land use change globally, converting forests and grasslands into cropland and pasture. Around 33 billion chickens, 1.5 billion cattle, and 1 billion sheep and goats used for meat and dairy occupy vast land areas, reducing biodiversity and fragmenting habitats (Pacifici *et al*., 2020).

Concurrently, urbanisation has accelerated: one-third of Earth's terrestrial surface is now used for agriculture, with Artificial surfaces expanding explosively in cities worldwide.

2.4.2 Drivers of Land Use Change in Africa

Across sub-Saharan Africa, rising market demand and human population increase are driving rapid conversions of shrubland and forest into farmland (Assede *et al.,* 2023). The IPBES Global Biodiversity Assessment (2020) identifies agricultural expansion as the dominant land use driver in the region (Davison *et al*., 2021). In Tanzania and neighboring countries, new agricultural frontiers have emerged, underpinned by global commodity demand and demographic shifts (Meyfroidt *et al.*, 2024).

2.4.3 Drivers of Land Use Change in East Africa

In Tanzania's Tarangire–Manyara ecosystem, a notable driver is the conversion of rangeland to agriculture, harvesting of wood resources, and increased rural settlement and fencing since 2020 (Wood *et al.*, 2021). This expansion has filled traditional migratory corridors used by elephants, wildebeest, and zebras, cutting off access to critical seasonal habitats. Wildlife corridor studies in the region highlight that as these agrarian zones expand, human-wildlife conflicts intensify alongside fragmentation of dispersal pathways (Elisa *et al.*, 2024)

2.4.4 Drivers of Land Use Change in Kenya

In Kenya, land use change is driven by transport infrastructure, urban growth, and agricultural expansion (Abuya, 2020). Analysis of the Standard Gauge Railway (SGR) corridor (2000–2019) found that artificial surfaces increased by 144%, bare land by 75%, and cropland by 9%, while grasslands and shrublands shrank by 67–98%. The principal drivers are population growth, urbanization, economic growth, and infrastructure development (Sang *et al.*, 2022). In dry land districts like Kibwezi West, land-cover change since 1990 has been attributed to population increases, agricultural intensification, industrialization, and major infrastructure works. Patterned land fragmentation is predicted to continue through 2050 without strategic planning (Omwoyo *et al.*, 2024).

2.5 Impacts of Land Use Changes on Wildlife

Land use changes around protected areas all over the world have a big impact on biodiversity, conservation efforts, and the services ecosystems provide (Petroni *et al.*, 2022). The growth of agriculture, infrastructure, and urban areas often pushes into nearby ecosystems, causing habitat fragmentation, a decline in biodiversity, and rising tensions between wildlife conservation and human livelihoods (Ramadhan, 2024).

2.5.1 Global Impacts of Land Use Changes on Migratory Ungulates

A worldwide review of 27 migratory ungulate species documented 127 migration-change events triggered by land use changes such as agriculture, roads, and fences (Xu *et al.*, 2021). These disturbances are causing shifts or cessation in migration timing and routes (McKee *et al.*, 2024). Additionally, infrastructure like solar farms is now recognized as disrupting ungulate movements, highlighting how human-landscape infrastructure fragments connectivity (Moore, 2024).

Malpeli (2022) documented that the 2020 *Ungulate Migrations of the Western United States: Volume 1* (USGS) provides a comprehensive set of migration maps for mule deer, elk, pronghorn, and others across the American West. This work highlights how highways, impermeable fencing, and expanding development increasingly fragment migratory routes, raising wildlife–vehicle collisions and limiting access to critical seasonal habitats (Kauffman et al., 2022).

2.5.2 Impacts of Land Use Changes on Migratory Ungulates in Africa

Recent assessments (2022–2024) on veterinary fences in the Kavango-Zambezi (KAZA) region, Botswana, demonstrate how fences obstruct migrations of wildebeest, zebra, buffalo, and giraffe (Swift, 2023). Fences block seasonal movements, leading to mortality by dehydration, entanglement, and increased poaching. Reports recommend targeted fence removals to restore connectivity (Rosen *et al.*, 2024). Long-standing evidence affirms that fences in the Okavango Delta have caused population declines and disrupted ungulate movements for decades (Morrison, 2021).

A 2020 GPS-tracking study in Namibia tracked springbok, kudu, and eland movement across wildlife-proof fence boundaries. The study found that fence crossings significantly altered their movement behavior, reducing travel speed and increasing time near fences, emphasizing the broader implications for energy budgets and habitat connectivity (Hering et al., 2022).

2.5.3 Impacts of Land Use Changes on Migratory Ungulates in East Africa

In the Nakasongola district in Uganda, remote sensing analysis shows agricultural land use grew from 7.2% in 1985 to 35.8% in 2021, while grasslands dropped from 31.7% to 18.5% (Burner *et al.*, 2025). Drivers included subsistence farming, overgrazing, fuel wood extraction, and population growth (Kuule *et al.*, 2022). These changes fragmented grassland

and wetland habitats, reducing forage availability and degrading habitats essential to ungulates and pastoralists alike (Chu *et al.*, 2022).

In Tanzania, studies since 2020 report that increasing agriculture, fencing, and settlement along the northern plains and Simanjiro corridor fragment migratory pathways for wildebeest, zebra, and elephants, reducing access to wet-season calving grounds and elevating human–wildlife conflict (Stabach *et al.*, 2022). Furthermore, ethnographic work reveals that farmers along these routes experience frequent crop raiding and threats from elephants and zebras, affecting both local livelihoods and wildlife safety (Raycraft *et al.,* 2024).

2.5.4 Impacts of Land Use Changes on Migratory Ungulates in Kenya

Changes in land use around Kenya's protected areas are influenced by a mix of factors like population growth, agricultural expansion, and infrastructure development (Kariuki *et al.,* 2021*)*. These shifts lead to significant ecological and socio-economic impacts (Shukla *et al.*, 2021). For instance, they cause habitat fragmentation, a decline in biodiversity, and increased conflicts between humans and wildlife (Bodo *et al*., 2021).

In the Mau Forest complex, deforestation and the encroachment of agriculture have seriously harmed ecosystems and threatened water resources, which in turn affects local livelihoods and conservation efforts (Oduor, 2022). Likewise, areas like Kitengela, Amboseli, and the Maasai Mara are experiencing urbanization and agricultural growth that disrupt traditional wildlife migration routes, especially for larger species such as elephants, which heightens human-wildlife conflicts (Kibet, 2024).

The Greater Maasai Mara fencing study directly highlighted problems in the Maasai Mara-Kitengela landscape, showing that fences completely block migrations of wildebeest and zebra between Nairobi National Park and the Athi-Kapiti Plains (Mwiu *et al.*, 2022). Historical land use reports confirm that Kitengela's subdivision and fencing initiated in the late 1980s has since narrowed dispersal zones, curtailed migration into Nairobi NP, and increased human–wildlife conflicts as wildlife movements are forced through smaller areas (Tyrrell *et al.,* 2022). The Nairobi National Park Wikipedia entry confirms that the southern boundary remains open, but development and fencing around Kitengela pose a growing threat to migratory paths (Burudi *et al.*, 2023).

A 2022–2024 study revealed dramatic increases in fencing and agricultural land conversion in southern Kenya's rangelands (Maasai Mara, Amboseli, Loita Hills, and South Rift Valley). This intensification has sliced through ungulate pathways, fragmenting habitat and escalating human–wildlife conflict(Tyrrell *et al.*, 2022). Recent genetic research further confirms that fencing disrupts gene flow in wildebeest populations resulting in reduced genetic diversity among isolated groups (Puyravaud *et al*., 2022).

2.6 Theoretical Framework of the Study

This research draws inspiration from Elinor Ostrom's Social-Ecological System (SES) framework, which offers a solid theoretical perspective for examining the intricate connections between ecological systems and human societies. As Ostrom pointed out in 2007, ecosystems and human communities aren't separate; they're intertwined, continuously affecting and evolving alongside one another. Our actions can influence the health of the environment, and conversely, shifts in the environment can lead to changes in how we behave.

The SES framework is crucial for grasping how resource users, governance structures, and ecological systems interact. It highlights that managing natural resources sustainably relies on effective governance that encourages collaboration among resource users while considering the condition of the ecological environment. Ostrom's research particularly champions the idea of communities coming together to manage shared resources, like those found in ecosystems such as Kitengela.

2.7 Conceptual Framework of the Study

A conceptual framework acts like a visual map that shows how independent variables, those drivers of land use change connect with dependent variables, which are the impacts on wildlife and human well-being (Hallaj *et al.*, 2024). This study takes its framework from Omoga (2020), building on the Millennium Ecosystem Assessment (MA) framework. The MA framework emphasizes the links between ecosystems, the services they offer, and how they relate to human well-being (Wang *et al.*, 2021).

This concept is vital for illustrating how human actions can transform ecosystems and how these shifts in ecosystem services can influence human well-being, both now and in the future. Grasping this relationship is a fundamental aspect of the Millennium Ecosystem Assessment, which also lays the groundwork for policy recommendations.

From the literature reviews, we can conclude that the main drivers of land use changes stem from demographic factors, infrastructure development, institutional and economic influences, pollution, climate change, land tenure systems, technological advancements, and government policies. These drivers lead to significant impacts on wildlife, as evidenced by current issues like habitat loss, restrictions on wildlife movement, declines in biodiversity, and reductions in wildlife populations. These effects also have indirect repercussions on human well-being (Figure 2.1).

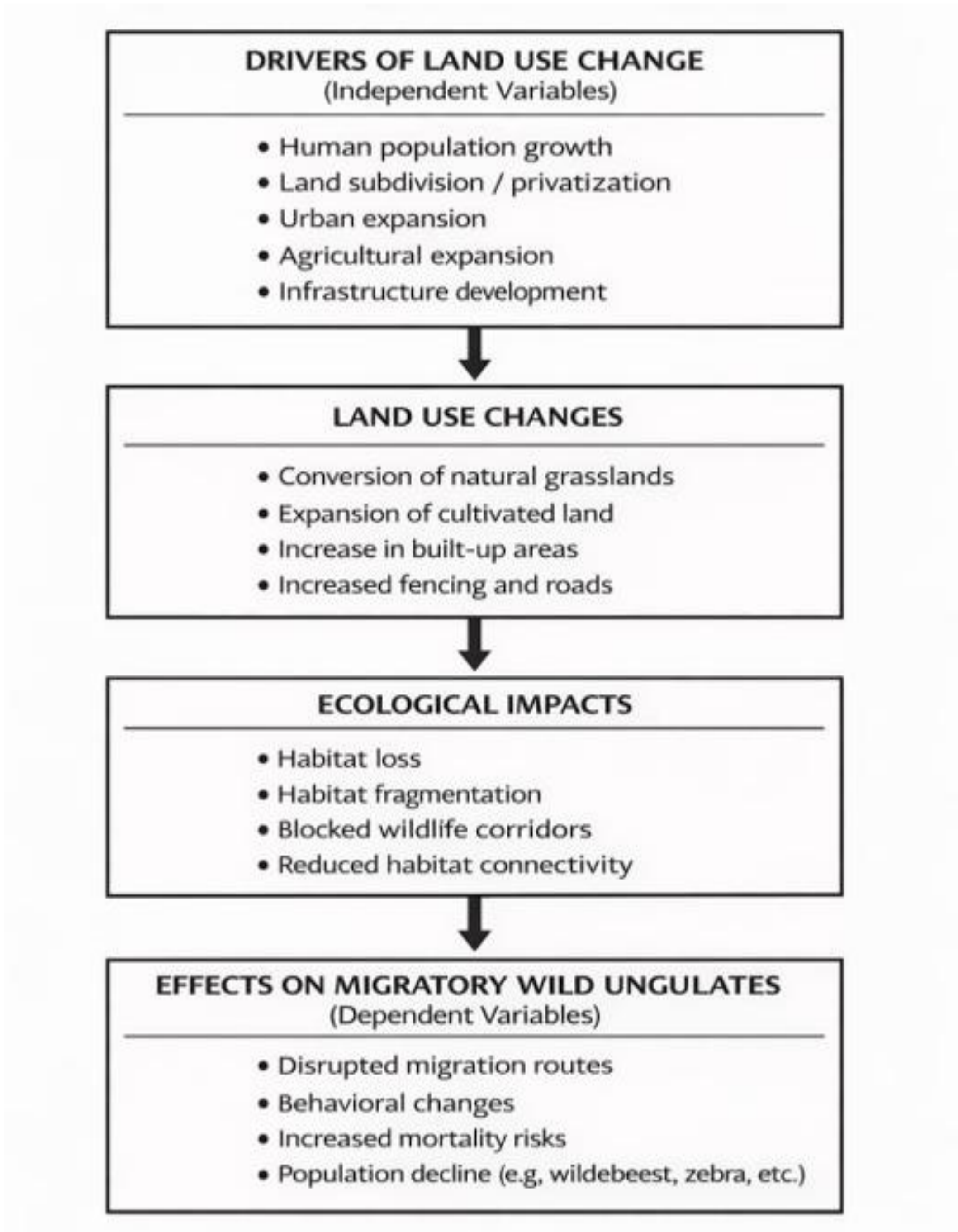

Figure 2.1 Conceptual framework of the study

(Source: Author, 2025)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

3.1.1 Location and Size

This research was done in and around the southern part of Nairobi National Park, which has been in existence since 1946 and is situated about 7 km south of Nairobi city (Mwangi *et al.,* 2022). Spanning 117 km², the park is located between the coordinates of 2°18'–2°20' S and 36°23'–36°28' E, with elevations ranging from 1,533 to 1,760 meters above sea level (Waturu, 2024). It's bordered by Nairobi County to the north, Machakos to the east, and Kajiado to the south, making it part of the larger 2,000 km² Athi-Kapiti plains (Profile, 2023).

Nairobi National Park is surrounded by an electric fence on the north, west, and east sides, while the southern edge remains open, allowing wildlife to migrate to the Kitengela dispersal area and the Athi-Kapiti plains (Nkedianye *et al.*, 2020). Kitengela, which used to be a pastoral grazing area without permanent settlements, is rapidly changing due to its closeness to Nairobi and a growing human population (Gichuru, 2022). This shift has led to changes in land use, including agriculture, urban development, and industrial expansion (Mwangi *et al.*, 2022).

The park is home to notable landmarks like the ivory burning monument, a conservation education centre, an animal orphanage, and a safari walk (Muritala, 2025). Several man-made dams within the park support birdlife and provide essential water sources for herbivores during the dry seasons (Koech, 2018).

Kitengela Conservation Area is a key wildlife corridor linking Nairobi National Park to the Athi–Kapiti ecosystem, which is experiencing rapid urbanization and habitat fragmentation, making it an ideal site for studying the impacts of land use change (Gichuru, 2022). Its active community-based conservation programmes and rich spatial and ecological datasets further enhance its suitability compared to other areas (Imanishimwe, 2022). The study area map was chosen based on the mapping done by the Regional Centre for Mapping of Resources for Development (RCMRD, 2013), which was also cited in earlier research by Wandaka and Francis (2019) (Figure 3.1).

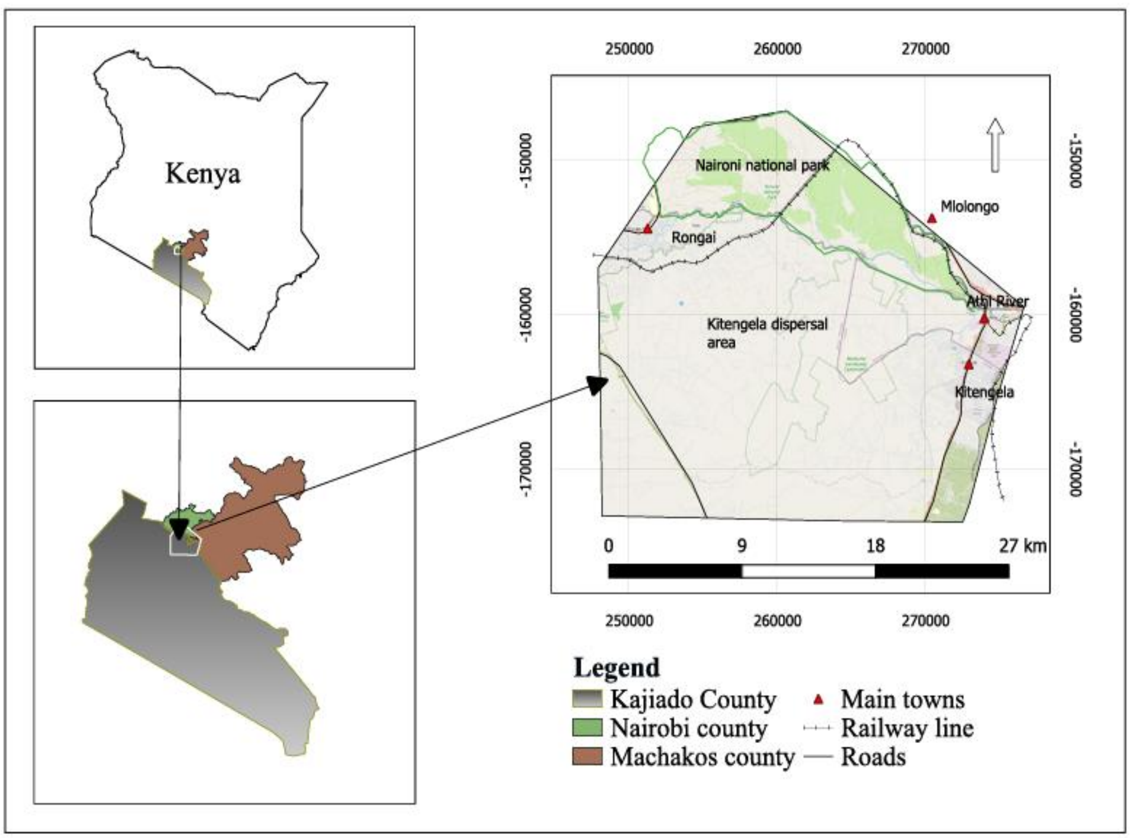

Figure 3.1 Location of Kitengela Conservation Area.

(Source: Author, 2025)

3.1.2 Climate

Climate plays a significant role in shaping human activities, the types of vegetation present, and their distribution, which in turn impacts the migration and distribution of wildlife (Xiong *et al*., 2023). As noted by Chen *et al.* (2024), the climate of any given region is influenced by factors like latitude, altitude, prevailing winds, topography, and how close it is to large bodies of water.

Kajiado County, where this study takes place, generally experiences a tropical dry climate with minimal local variations. Rainfall in the area is heavily influenced by altitude, ranging from 500 mm to 1250 mm annually (Achola, 2021). The northern parts of the county, particularly near the Ngong Hills and Nairobi, receive the most rainfall, while the southern areas, which are at lower elevations, see the least (Mwangi, 2020). Rainfall patterns are bimodal, featuring alternating wet and dry seasons. The long rains typically occur from March to May, while the short rains fall between November and December (Maina, 2020). In between these rainy periods, there are dry spells from January to March and from June to October (Nkedianye *et al.*, 2020).

Temperature in this region varies with altitude, with annual mean temperatures ranging from 13.5°C to 25.3 °C (Onyango, 2024). The hottest months are from November to April, while the coldest are July and August (Mungai, 2022). During the wet seasons, migratory wildlife tend to move out of the park but return during the dry seasons (Gichuru, 2022).

3.1.3 Geology and Soils

The geology of the park and its surroundings was detailed by Scoon (2022), who noted that it's covered by a series of lava flows. In the western part of the park, you'll find Nairobi trachyte, which is marked by its grey mottled lava that sparkles thanks to countless tiny feldspar crystals. Moving to the central plains, Nairobi phonolite takes the stage, featuring smaller nepheline and fewer feldspar crystals, with the occasional small Biotite flake making an appearance. Throughout the park, Mbagathi phonolytic trachyte can be spotted, containing feldspars, nephelines, and phenocrysts. In the rocky valleys and bushy areas of the park, you'll come across Athi tuft, which has a soft and crumbly texture.

Scott (1963) described the soils in the area, noting that the summit, upper, and middle slopes are made up of red clay soils. The lower slopes, on the other hand, have shallow soils resting on laterite, while the depressions are filled with clay soils. In the central plains, the soil is a mix of dark brown calcareous clays, reddish-brown sandy clay loams, and alluvial soils. The flat plains feature shallow yellow-brown to yellow friable clays that sit above a laterite layer, along with shallow soils and alluvial soils.

3.1.4 Topography and Drainage

The Kitengela conservation area features a gently rolling landscape, where the land gradually slopes down from the western and central regions of Nairobi National Park (NNP) towards the Embakasi plains and the Athi River.

Numerous streams cut through the area, starting from the western and northern edges of NNP and flowing towards the Mbagathi River. In addition to the Mbagathi and Athi Rivers, there are several other seasonal streams that gather water from the west and eventually drain into the Athi River (Munyoki, 2024).

This region struggles with drainage, mainly because of its gentle slopes and the type of soil present. These factors play a significant role in how water is retained, the moisture levels in the soil, and the overall patterns of land use in the surrounding area.

3.1.5 Fauna and Flora

The park is dominated by open grass plains with scattered acacia trees, classified into eight vegetation types: closed dwarf tree grasslands, open low grasslands, general grassland, scattered low-tall tree grassland, open dwarf tree grassland, open tall riverine woodland, forest glades, and dense tall forest (Luke & Beentje, 2020; Mwangi et al., 2022).

The Kitengela area, which serves as a key wildlife dispersal zone, consists mainly of dry savannah grasslands with scattered Acacia species, Balanites species, and *Euclea divinorum*, providing forage for migratory ungulates (County Government of Kajiado, 2019).

The area supports diverse wildlife, including lions, leopards, African buffalo, black rhinoceros, giraffes, hippopotamuses, spotted hyenas, blue wildebeests, plains zebras, cheetahs, Thomson's and Grant's gazelles, common elands, impalas, hartebeests, waterbucks, warthogs, olive baboons, jackals, ostriches, and Nile crocodiles (Mwangi et al., 2022). Kitengela also hosts many of these species, particularly herbivores during the wet season, and provides habitat for birds, with over 500 permanent and migratory species recorded (Mwangi et al., 2022).

3.1.6 Socio-Economic Activities

Traditionally, pastoralism was the mainstay of the economy in rural Kitengela, deeply influenced by the semi-arid landscape and the local culture. But as the population keeps growing and land becomes scarcer, the community, now a mix of migrants from various ethnic backgrounds both within and outside Kenya, has begun to branch out into different economic activities to meet their daily needs (Mikula *et al.,* 2022).

In certain areas of Kitengela, people have taken up subsistence farming, primarily growing beans and maize (Nkedianye *et al.*, 2020). The local economy has become a tapestry of various sectors, including crop farming, livestock rearing, trade and commerce, industries, mining, and the commoditization of land. These changing economic trends reflect a shift in livelihood strategies, driven by evolving demographic and environmental factors in the region (Moreda, 2023).

3.1.7 Land Use

The Kitengela conservation area is encircled by a mix of urban and commercial activities, such as residential settlements, irrigation projects, farms, quarries, industries, and schools (Makau, 2021). These developments have spurred job creation, drawing in a larger population to the area.

As the number of residents has surged, housing developments have spread to accommodate the growing community. Over the last ten years, the region has experienced notable changes in land use, particularly due to infrastructure growth (Araka, 2021). This is evident in the construction of roads, buildings, fences, and, more recently, the Standard Gauge Railway (SGR) (Personal Communication with Kajiado County Senior Warden, KWS, 2022).

3.1.8 Water Sources

As mentioned in section 3.1.2 above, the Kitengela ecosystem experiences a bimodal rainfall pattern, with a longer rainy season from March to May and a shorter one from October to December (Marchant & Marchant, 2021). Unfortunately, the area lacks enough surface water sources to support the diverse range of living organisms, including livestock, wildlife, and humans. As a result, everyone relies on groundwater sources (Gichuru, 2022). Other alternative water sources include subsurface options like shallow wells, dams, and water pans (Mandela, 2020). While different regions within the plains have various water sources, the primary water supply for Nairobi National Park (NNP) comes from the Mbagathi River (Munyoki, 2024). There are also several seasonal rivers, such as Olomanyi, Kiembe, Sosian, and Makoiyet, that provide water. Additionally, NNP has 15 dams built to help meet the water needs of wild animals during the dry seasons (Nyabonyi *et al.,* 2023).

3.2 Research Design

A research design is essentially the approach used in a study to find answers to research questions (Berman *et al.*, 2020). This study adopted a descriptive research design within a mixed-methods framework. The design was appropriate because the study sought to describe, analyze, and interpret patterns of land use change and their implications for migratory wild ungulates in the Kitengela Conservation Area over time. Quantitative methods were used to assess land use/land cover changes from Landsat imagery, trends in wild ungulate populations, and human population dynamics between 1988 and 2020.

Qualitative methods, including household questionnaires, key informant interviews, field observations, and photography, were used to capture local perceptions on the drivers of land use change and its impacts on wildlife.

3.2.1 Nature of Data Required

This study required both quantitative and qualitative data. Quantitative data included Landsat satellite imagery for 1988, 2000, 2010, and 2020; land cover class statistics; archival records of migratory wild ungulate populations from Kenya Wildlife Service; and human population data obtained from official census sources. These datasets were necessary for analyzing temporal land use changes, wildlife population trends, and human population dynamics in the Kitengela–Nairobi National Park ecosystem.

Qualitative data included household responses on perceived drivers of land use change and perceived impacts on wild ungulates, key informant interview responses from KWS, NEMA, NGOs, private ranchers, and community-based organizations, as well as field observation notes and photographs documenting visible land use changes and ecological disturbances in the study area. These data were used to explain the causes of land use change and interpret their ecological consequences.

3.2.2 Materials Required for The Study

The project made use of a variety of hardware and software tools to streamline the process of data collection and analysis (Table 3.1).

Table 3.1 Materials used in the study

Tool	Purpose	Linked Objective.
QGIS 3.24.3	Land cover classification, spatial analysis of satellite imagery	Objective 1: Analyze land use changes.
GPS Device	Ground truthing of classified land cover	Objective 1: Validate spatial data.
Camera	Visual documentation of land use impacts	Objective 4: Assess physical impacts on wildlife habitats.
SPSS v23	Statistical analysis of survey and KII data	Objective 3 & 4: Identify drivers and impacts of land use change.
Microsoft Excel	Tabulation of land use data and demographic statistics	All objectives.
Microsoft Word	Report writing and documentation	All objectives.

3.2.3 Target Population

A target population refers to a complete group of individuals, events, or objects that share common traits (Willie, 2024).

As noted by Khan (2024), the target population is the overall set of individuals, events, or objects in a study, whether they exist in reality or are hypothetical that a researcher aims to conclude about. In this research, the target population included all residents of the Kitengela wildlife conservation area in Kajiado and Machakos Counties, along with various stakeholders involved in wildlife conservation efforts within Nairobi National Park and its surrounding areas. These stakeholders comprised Non-Governmental Organizations, the Kenya Wildlife Service, the National Environment Management Authority, and private ranchers operating in the region. When it comes to spatial data, the main target elements were vegetation, bare land, artificial surfaces, and cultivated land.

3.2.4 Sampling Procedures

The data collection process was structured around a three-stage sampling method. First, the downloading of Landsat satellite images from the Earth Explorer web platform to gather spatial data for land use classification. Next was a collection of secondary data, including archival records on migratory wild ungulates from the Kenya Wildlife Service and human population statistics from the Kenya National Bureau of Statistics, to show relationships with land use changes. Finally, socio-ecological data were collected using various methods, such as; questionnaires, key informant interviews, observation sheets, and photography to capture unique incidents, activities, and events relevant to our study.

3.2.5 Sample Selection

Sample selection was done using systematic and random sampling techniques. Random sampling was used to select the first household, followed by systematic sampling, picking every alternate household due to the sparse settlement patterns outside the park. The purposive sampling method was also employed to identify key informants who could offer valuable insights. These informants included representatives from non-governmental organisations, the Kenya Wildlife Service, the National Environment Management Authority, private ranchers, and community-based organisations working in the study area. Sampling bias was minimized by selecting respondents from different stakeholder groups within the Kitengela Conservation Area, including both local Maasai households, who are the original landowners, and non-Maasai households that have purchased land in the region. This ensured diverse perspectives and reduced over-representation of a single group.

According to Nkedianye *et al.* (2020), local communities living within the Kitengela ecosystem live in three main village clusters, which together consist of a total of 918 cluster households (Table 3.2).

3.2.6 Sample Size

A sample size is a sub-section of a population that is chosen in such a way that its characteristics reflect those of a group from which it was chosen. (Watson & Lynn, 2021). This study adopted the Yamane (1973) formula used by Nelly *et al.* (2021).

The sample size was calculated as follows;

$$\mathrm{n} = \frac{N}{1+N(e^2)} \tag{1}$$

Where n − Sample size

N − Population size

e − Margin of error

Based on the above formula, the household sample size for this study was determined to be 109 households, with a margin of error set at 9% (91% confidence level) due to financial constraints, which limited a bigger sample size. As indicated by Nelly *et al.* (2021), the sample size for each village cluster was calculated by determining the proportion of the cluster's population relative to the total population and multiplying this fraction by the household sample size (Table 3.2).

$$\text{Village cluster 1} = \frac{403}{918} \times 109 = 48 \text{ cluster households}$$

$$\text{Village cluster 2} = \frac{485}{918} \times 109 = 58 \text{ cluster households}$$

$$\text{Village cluster 3} = \frac{30}{918} \times 109 = 4 \text{ cluster households}$$

$$\text{Total} = 110 \text{ cluster households}$$

Table 3.2 Kitengela village clusters

Kitengela village clusters	Household cluster	Sampled household cluster
1. Oloosirkon, Olooloitikoishi, Sholinke, Kisaju	403	48
2. Empatipat, Empuyiankat, Olturoto, Illasit, Enkirgirri, Ilpolosat	485	58
3. Nado Enterit	30	4
Total	918	110

Purposive sampling was used to select ten key informants, ensuring the inclusion of stakeholders with relevant expertise. These informants comprised two representatives from the East African Wildlife Society (EAWLS), two from the Kenya Wildlife Service, one from the National Environment Management Authority, two private ranchers, and three representatives from Community-Based Organizations operating in the study area. This gives a total sample size for the study of 120 respondents.

3.3 Data Collection, Analysis and Presentation

To investigate land use changes and their impacts on migratory wild ungulates in the Kitengela Conservation Area, a mixed-methods approach was employed, combining remote sensing, field surveys, structured questionnaires, and key informant interviews (KIIs). This approach allowed for both quantitative and qualitative data to be collected from multiple sources, improving the reliability and richness of the findings.

Accuracy in data collection and analysis was ensured by using standardised questionnaires, cross-checking responses, and verifying secondary data from reliable institutions such as the Kenya Wildlife Service and the Kenya National Bureau of Statistics. Data were carefully organized and analyzed to minimize errors and improve the reliability of the results.

3.3.1 Acquisition of Landsat Images

To evaluate how land use has changed in the Kitengela conservation area, various Landsat satellite images were gathered and analysed. Four images from 1988, 2000, 2010, and 2020 were obtained during dry season in their raw, unprocessed form from the Earth Resources Observation and Science (EROS) Center via the United States Geological Survey (USGS) Earth Explorer platform (Earth Explorer), and were specifically analyzed.

When selecting the right Landsat images, several factors were taken into account, such as cloud cover, the time of year, availability of images for the specific years (Hemati *et al., 2021)*, and the overall quality of the images. Only images with minimal cloud cover were processed. However, some challenges were faced in certain years due to data gaps or a lack of high-quality imagery for 1990. In these instances, the closest available image from either the year before or after is used (Nagaraj *et al.*, 2020). For instance, to examine changes from 1990 to 2020 at ten-year intervals, a suitable image for 1990 was not available, so the 1988 Landsat image was used as a substitute (Table 3.3).

Table 3.3 Characteristics of Landsat satellite images used in the study

Landsat scenes	Sensor	Acquisition date	Path & Row	Resolution (m)
LT04_L1TP_168061_19880124	Landsat 04 TM	24-01-1988	168/61	30 × 30
LE07_L1TP_168061_20000221	Landsat 07 ETM	21-02-2000	168/61	30 × 30
LT05_L1TP_168061_20100819	Landsat 05TM	19-08-2010	168/61	30 × 30
LC08_L1TP_168061_20200830	Landsat 08 OLI_TIRS	30-08-2020	168/61	30 × 30

3.3.2 Processing of Landsat Images

Landsat satellite images were downloaded from Earth Explorer and processed using GIS tools in Quantum Geographical Information System (QGIS) 3.24 Tisler. The images were first rectified to align with a common Universal Transverse Mercator (UTM) projection (specifically UTM zone 37S) and resampled to ensure a consistent spatial resolution. With these processed images in hand, land use maps were generated for the study area.

Unprocessed image bands were imported from the Landsat satellite into QGIS and merged into a single multispectral band using the composition band tool. The area of interest was then clipped, which corresponded to our study area, and from the composite image, we classified it to identify different land use categories.

3.3.3 Land Use Classification

a) Visual Image Classification

Image visualisation got a boost by enhancing various feature distinctions, all to optimize the unique strengths of both the human brain and computers. This process was all about tweaking images to better match how things could be seen.

In the study, only two techniques were used: contrast enhancement and band combinations. Different combinations of satellite image bands were tested and showcased to create a range of composite effects, which helped in interpreting changes in land use. The most frequently used band compositions included false colour composition, True color composition, and Natural color composition. These methods made it easier to grasp spatial patterns and shifts in land use within the study area.

b) Digital Image Classification

Image digitisation aimed to sort pixels in the satellite images into specific land cover classes, based on digital number values that reflect the spectral properties of the ground surface. This involved grouping regions (or pixels) in Landsat images into classes that matched different land cover types, guided by data-driven decisions based on observations from the study site.

The image classification followed Anderson's (1976) Level I generalised classification system, utilizing the maximum likelihood supervised classification tool in QGIS. This system is particularly effective for gathering broad land use information and is tailored for Landsat data.

The classification process started with the creation of areas of interest (AOIs) or training sites, where different land use categories in the Landsat images were assigned signature names. Small sections of each land use class were digitized to set up training sites based on ground truth data. After that, supervised classification was performed on the Landsat images from 1988, 2000, 2010, and 2020, using a categorized classifier, either through created ROI polygons or activated ROI pointers. This organized approach ensured a detailed and accurate representation of land use dynamics over time (Figure 3.2).

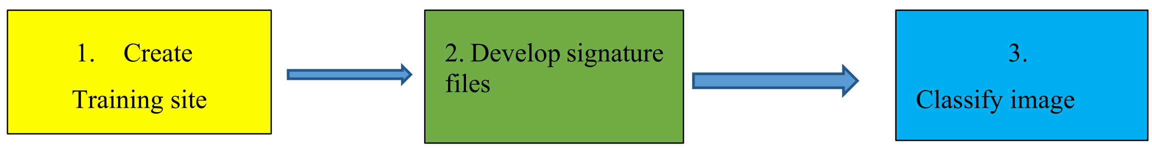

Figure 3.2 Supervised classification diagrams

Under the land use classification process, the identified land use types were categorised into seven major classes. These classifications provide a structured understanding of land use patterns within the study area, enabling a clear analysis of spatial transformations over time (Table 3.4).

Table 1.4 Land use classes with their descriptions

Land use class	Description
1. Riverine vegetation	This class refers to a mixed deciduous and evergreen forestland.
2. Shrubland	Land covered by small trees and bushes in which shrubs are the dominant vegetation. Closed to open (thicket) (15–100%) scattered trees
3. Grassland	Area under continuous cover of grasses. Herbaceous closed vegetation (15–100%) with some trees, shrub savannah, and permanent marsh
4. Cultivated land	Areas where the natural vegetation has been removed or modified and replaced by other types of vegetative cover of anthropogenic origin. All vegetation that is planted or cultivated with intent to harvest is included in this class.
5. Bare land	Bare rock and/or coarse fragments. Areas that do not have an artificial cover as a result of human activities. These areas include areas with less than 4% vegetative cover.
6. Water bodies	This class refers to areas that are naturally covered by water, such as dams, lakes, rivers, snow, or ice
7. Artificial surfaces	Areas that have an artificial cover as a result of human activities, such as construction (cities, towns, and transportation), extraction (open mines and quarries), or waste disposal

(Source: Modified from Encyclopedia of Soil in the Environment 2005)

3.3.4 Ground Truthing

A reconnaissance visit to the Kitengela conservation area was conducted to get a good look at its physical features and overall environmental conditions. Ground truth data was gathered between June 2, 2022, and August 20, 2022, and became an essential resource for classifying images and assessing their accuracy.

To ensure all land use classes were covered, the random sampling method for ground verification was used, thus ensuring the sample points were well-distributed throughout the study area (Esfandiari *et al.*, 2020). Although a standard of 50 sample points for each land use class was aimed at, for relatively sparse water bodies, 19 sample points were created from them (Zhang *et al*., 2022).

A Global Positioning System (GPS) was used to capture precise coordinates for the selected sample points, which helped in accurately interpreting the downloaded satellite imagery and confirming real-world conditions (Jiang *et al*., 2022; Klemmer *et al.*, 2025). Some photos were snapped to further back up the accuracy of the classified Landsat satellite images.

3.3.5 Accuracy Assessment

To evaluate how accurate the classification process was, a statistical test that compared the classified data with ground truth or other reliable sources was employed (Foody, 2024). The accuracy assessment method involved a comparison technique, where testing points against the classified image for each land use class were matched.

For the accuracy assessment, sampling pixels were selected using a randomly stratified sampling method, with detected change pixels forming the basis for stratification. Over 40 sample ROIs for each land use class for the years 2010 and 2020 were picked. Unfortunately, an accuracy assessment for 1988 and 2000 could not be done due to challenges in obtaining historical reference data or reliable aerial photographs. It was assumed that the accuracy assessment of the 2010 and 2020 maps would give a reasonable idea of the accuracy for the classified maps from 1988 and 2000 (Mucova *et al.*, 2018).

The evaluation of accuracy was carried out using four main metrics: overall accuracy, user's accuracy, producer's accuracy, and the Kappa coefficient error matrix (Feizizadeh *et al.,* 2022). One of the standout benefits of this accuracy assessment approach is its capability to pinpoint the type, nature, and number of errors linked to the classification process. In thematic classification, an overall accuracy of 85% or higher is deemed acceptable, as long as the accuracy for each class hits at least 70% (Kija *et al.*, 2020).

The following equations were used to compute the accuracy of the classified images:

$$\text{Producer Accuracy} = \frac{\text{Correctly classified pixels in a class}}{\text{Total pixels in the reference for that class}} \tag{2}$$

$$\text{User Accuracy} = \frac{\text{Correctly classified pixels in a class}}{\text{Total pixels classified in that class}} \tag{3}$$

$$\text{Overall Accuracy} = \frac{\text{Sum of correctly classified pixels}}{\text{Total number of pixels}} \tag{4}$$

$$\text{Kappa Index} = \frac{\text{Observed accuracy} - \text{Expected agreement by chance}}{1 - \text{Expected agreement by chance}} \tag{5}$$

$$\text{Expected agreement by chance} = \frac{\text{sum of row total} * \text{sum of column total}}{\text{Total pixels}^2} \quad (6)$$

The flowchart below (Figure 3.3) summarises the process of land use classification.

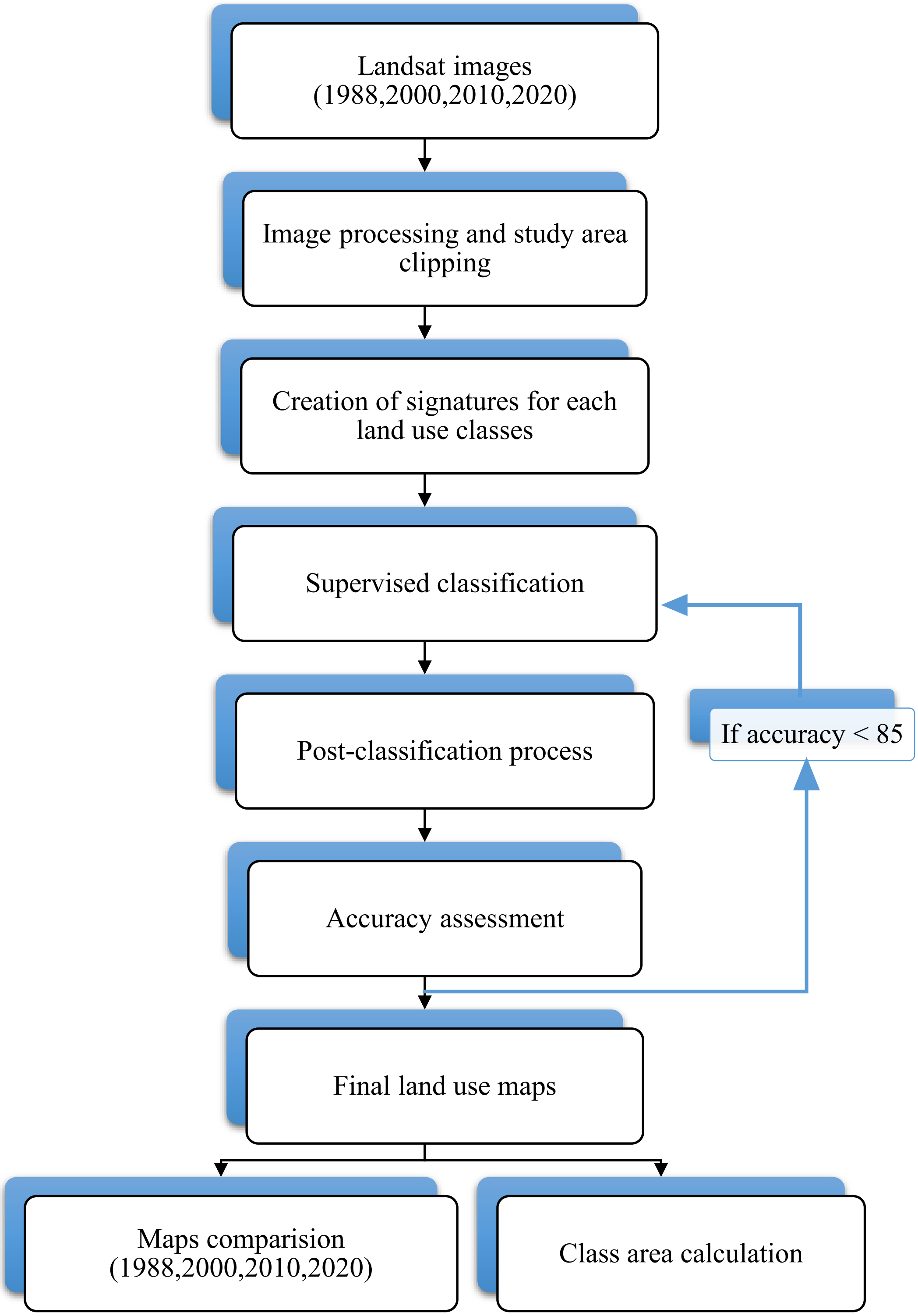

Figure 3.3 Methodology adopted in classifying land use

Land use changes from 1988 to 2020 were analysed using descriptive statistics. Data were gathered on various land use categories like riverine areas, grasslands, cultivated fields, artificial surfaces, water bodies, and shrublands for the years 1988, 2000, 2010, and 2020. All this information was compiled and analyzed using Microsoft Excel, and bar graphs were used to illustrate trends. To find the absolute changes, the land use area for 1988 was subtracted from that of 2020, and the percentage change was calculated using a specific formula.

$$\text{Percentage of land use change} = \frac{A_{year\ i+1} - A_{year1}}{\sum_{i=1}^{n} A_{year1}} \times 100 \qquad (7)$$

Where $A_{year}\ i$ is the area of land cover i at the first date, $A_{year\ i+1}$ is the area of land cover at the second date, and n is the number of years within an interval (Kiggundu *et al*., 2018). This helped identify major transformations, such as urban expansion into former grasslands, while change detection maps highlighted spatial transitions between land use types over time. These visuals helped identify major transformations, such as urban expansion into former grasslands.

3.3.6 Relationship among Humans, Land Use Change, Wildebeest, and Zebra Populations

Information on human and migratory wild ungulate populations in Kitengela Conservation Area from 1988 to 2020 was obtained from various secondary sources to determine long-term ecological trends. The population figures for wildebeest and zebras were from annual aerial and ground surveys conducted by the Kenya Wildlife Service (Owino *et al.,* 2011; KWS, 2020), which utilized both direct counts and sample block counts. For human population statistics, data used was from the Kenya National Bureau of Statistics (KNBS) during the census for 1989, 1999, 2009, and 2019. These were the nearest available census years and to bridge the gaps between these census years, linear interpolation was applied, assuming a steady growth rate, which allowed us to create a continuous demographic time series.

Data collected were meticulously cleaned, standardised, and validated through literature reviews and expert consultations. This final dataset provided a solid foundation for analysing trends and testing correlations. Spearman's rank correlation was used to evaluate the statistical relationships between human population growth and changes in wildlife populations, determining significance at the 95% confidence level ($\alpha = 0.05$).

3.3.7 Field Survey

A field survey was carried out to collect firsthand data from the study area through household interviews, conversations with selected community members and direct observation. The goal of this fieldwork was to delve into the factors driving land use changes and their effects on the habitat, mortality, and behaviour of migratory wild ungulates in the Kitengela conservation area. To ensure accurate geographic referencing, GPS technology was employed to log the locations of the surveyed households, which also helped validate the interpretations of satellite imagery. This geospatial data significantly enhanced the precision of land use mapping and analysis (Zhang & Li, 2022).

a) Questionnaire Surveys

To assess community views on land use changes and their ecological consequences, a structured questionnaire was distributed to 110 residents living in the Kitengela Conservation Area. The questionnaire aimed to gather both quantitative and qualitative insights, focusing on two main areas: demographic and land use information, as well as perceptions of land use changes and their impacts on wildlife. It included a mix of closed-ended questions (multiple choice) and open-ended questions to encourage detailed responses on important topics. To ensure a diverse representation across different socio-economic groups and geographical areas, purposive and stratified random sampling methods were utilised to select respondents.

Data gathered were cleaned up, coded, and entered into Microsoft Excel and then imported into Statistical Package for Social Sciences (SPSS) for analysis. Descriptive statistics, like frequencies and percentages, were used to summarize the demographic variables and community perceptions, and graphs and tables were used to present results.

The chi-square goodness-of-fit test was used to test for statistical differences in community perceptions. This test was crucial in determining whether the variations observed in the perceived drivers and impacts of land use change were significantly different from what would be expected in a uniform distribution. Perceived impacts of land use changes on habitat, mortality, and behavioral responses were categorized into thematic impact categories, namely, habitat-related, mortality-related, and behavioral impacts and analyzed both qualitatively and quantitatively. Themes and drivers of land use changes were later cross-tabulated with socio-demographic variables to identify significant patterns.

b) Key Informant Interviews

Alongside the household surveys, ten Key Informant Interviews (KIIs) were carried out with individuals who have extensive knowledge of the Kitengela ecosystem, including conservation officers, NEMA representatives, and members of community-based organisations. The purpose of these interviews was to obtain in-depth information that helped in understanding underlying trends in land use change, examine the challenges and opportunities that arise from these changes, and provide a richer context for the quantitative survey findings.

A structured checklist was used to guide the KIIs to ensure data was collected consistently and comprehensively. Qualitative data obtained from key informants were used to provide contextual insights and explanations that complemented the quantitative findings of this study. The information helped interpret patterns observed in the data and offered expert perspectives on land use change and wildlife impacts.

3.4 Ethical considerations

The researcher secured permission to carry out the study from both the National Commission for Science, Technology and Innovation (NACOSTI) and the Kenya Wildlife Service.

Further, the researcher had a responsibility to uphold the confidentiality of all participants, making sure their identities were kept private, particularly for vulnerable groups where extra care was taken to avoid any possible harm. The researcher also ensured that confidentiality was rigorously maintained when accessing personal information or details about participants' social lives, protecting their privacy throughout the research process.

CHAPTER FOUR

RESULTS

4.1 Land Use Changes That Have Occurred in Kitengela Conservation Area

Results revealed significant land use changes in the Kitengela conservation area between 1988 and 2020. A clear Landsat image for 1990 could not be obtained, so 1988 was used as the baseline. Notable among these are a shift from pastoralism to agriculture (crop farming), increased urbanization, industrial development, mining and increased settlement in the area. During the land use mapping process, seven unique land use classes were identified: riverine vegetation, shrub-land, grassland, cultivated land, bare land, water bodies, and artificial surfaces (Table 3.3). These categories laid the groundwork for classifying land cover and tracking changes throughout the study period.

In 1988, which served as our baseline year, shrubland was the most prevalent land type, covering 42.31% (249.34 km²) of the area. Grassland followed closely at 38.81% (228.76 km²), while riverine vegetation made up 11.44% (67.42 km²). Cultivated land (0.32%) and water bodies (0.06%) occupied only small portions, highlighting the region's pastoral land use. Overall, vegetation-based cover accounted for a whopping 92.56% (545.52 km²), with bare land and artificial surfaces making up 6.59% and 0.46%, respectively.

By 2000, riverine vegetation and grassland had declined to 43.26 km² and 197.27 km², respectively. Meanwhile, shrubland expanded to 286.85 km². Artificial surfaces nearly doubled, reaching 5.26 km² (0.89%), and bare land increased to 53.76 km², with cultivated land also seeing a slight increase.

By 2010, artificial surfaces had grown even more, now representing 2.09% of the area, while grassland decreased to 30.90 km². Riverine vegetation made a slight comeback at 45.28 km², which could be attributed by regrowth of shrub land, but shrub-land, bare land, and cultivated land all experienced modest declines.

By 2020, the impact of human activity on land use had intensified. Riverine vegetation fell to 26.92 km², and both grassland and shrubland decreased to 180.60 km² and 191.53 km², respectively. In contrast, artificial surfaces surged to 44.81 km² (7.60%). The increases in bare and cultivated land further underscored the growing human influence and transformation of the landscape (Figure 4.1 and Table 4.1).

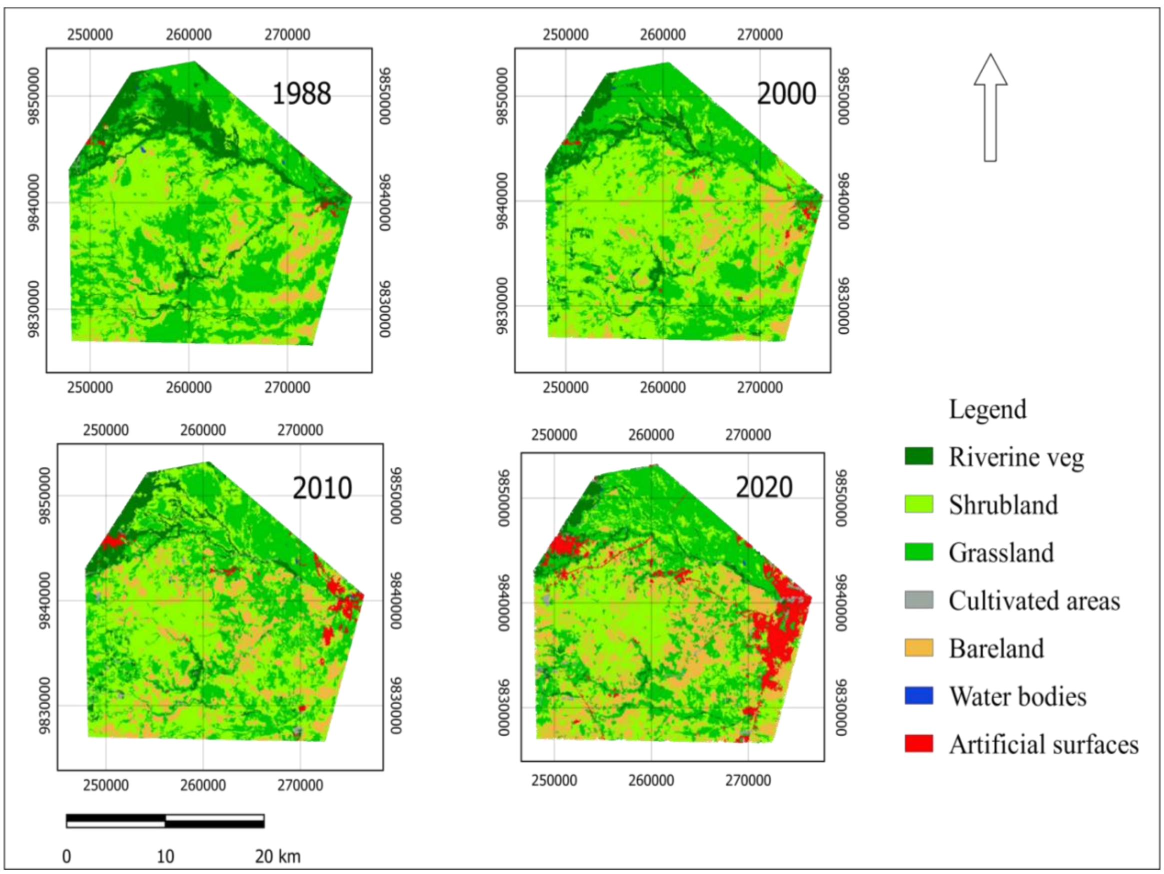

Figure 4.1 Land use classified map of Kitengela conservation area

Table 4.1 Land use classes and their proportions in the Kitengela dispersal area

Land use classes	**1988**		**2000**		**2010**		**2020**	
	Area (km²)	**%**	**Area (km²)**	**%**	**Area (km²)**	**%**	**Area (km²)**	**%**
Riverine vegetation	67.42	11.44%	43.26	7.34%	45.28	7.68%	26.92	4.57%
Shrubland	249.34	42.31%	286.85	48.67%	250.31	42.47%	191.53	32.50%
Grassland	228.76	38.81%	197.27	33.47%	182.09	30.90%	180.60	30.64%
Cultivated land	1.89	0.32%	2.60	0.44%	9.36	1.59%	15.81	2.68%
Bare land	38.85	6.59%	53.76	9.12%	89.67	15.21%	129.31	21.94%
Water bodies	0.37	0.06%	0.36	0.06%	0.35	0.06%	0.38	0.06%
Artificial surface	2.74	0.46%	5.26	0.89%	12.30	2.09%	44.81	7.60%
Total	589.37	100%	589.37	100.00%	589.37	100%	589.37	100%

4.1.1 Accuracy Assessment of Classified Land Use Classes

The accuracy of the land use classification for 2010 and 2020 was assessed using error matrices (Table 4.2 and Table 4.3). For 2010, the overall classification accuracy stood at an impressive 90.02%, with a Kappa coefficient of 0.89. This indicates a strong alignment between the classified map and the reference data. In a similar vein, the land use classification for 2020 recorded an overall accuracy of 89.19%, accompanied by a Kappa coefficient of 0.87. These findings imply that the classification process for both years was dependable, and the resulting maps are well-suited for further exploration of land use change dynamics in the Kitengela conservation area.

Table 4.2 Results of accuracy assessment of land use classes for 2010

Land use classes	Producer's accuracy (%)	User's accuracy (%)	Overall accuracy (%)	Kappa coefficient
Riverine vegetation	87.00	87.04		
Shrubland	98.00	86.00		
Grassland	85.00	94.00		
Cultivated land	92.00	87.19	90.02	0.89
Bare land	94.03	85.33		
Water bodies	89.11	87.50		
Artificial surfaces	88.00	91.65		

Table 4.3 Results of accuracy assessment of land use classes for 2020

Land use classes	Producer's accuracy (%)	User's accuracy (%)	Overall accuracy (%)	Kappa coefficient
Riverine vegetation	85.00	83.30		
Shrubland	92.20	97.45		
Grassland	87.21	91.38		
Cultivated land	88.14	85.00	89.19	0.87
Bare land	89.33	80.00		
Water bodies	90.50	89.23		
Artificial surfaces	93.70	88.49		

4.1.2 Land Use Change Detection Analysis

Land use change detection was conducted to pinpoint and measure areas that underwent transformations during the study period. This involved comparing classified land use maps from four different time points, analysing the changes in pixel values tied to each land use category. By doing percentage land use change analysis and both spatial and temporal variations, we were able to uncover trends in land use changes, differentiate between stable and altered land cover types, and identify specific regions that experienced significant shifts. This comparison offered valuable insights into the dynamics of land use within the Kitengela conservation area.

4.1.2.1 Percentage Land Use Changes in Kitengela Conservation Area

A percentage land use change analysis was used to determine land use changes in the area from 1988 to 2020. Cultivated land and artificial surfaces saw the most dramatic increases, with expansions of 737.04% and 1535.40%, respectively, due to human population growth, which resulted in demand for settlement areas and farmland. On the flip side, natural land cover types faced significant declines, including a 60.07% drop in riverine vegetation, a 23.19% decrease in shrubland, and a 21.05% reduction in grassland.

Additionally, bare land and water bodies rose by 232.84% and 2.70%, respectively. These trends clearly indicate that land use changes have been consistently occurring over each decade, underscoring the ongoing human impacts and environmental shifts within the Kitengela conservation area (Table 4.4).

Table 4.4 Percentage land use changes in Kitengela conservation area

	Percentage land use change			overall % change
Land use types	1988-2000	2000-2010	2010-2020	1988-2020
Riverine vegetation	-35.84	+4.67	-40.55	-60.07
Shrubland	+15.05	-12.74	-23.49	-23.19
Grassland	-13.77	-7.70	-0.82	-21.05
Cultivated land	+37.57	+260.00	+69.02	+737.04
Bare land	+38.38	+66.80	+44.21	+232.84
Water bodies	-2.70	-2.78	+8.57	+2.70
Artificial surfaces	+91.97	+133.84	+264.31	+1535.4

4.1.2.2 Comparison of Temporal Classified Land Use Maps

Detecting changes in land use within the Kitengela Conservation Area over a span of 32 years was carried out using the Principal Components Classification (PCC) method in QGIS. This approach was chosen due to its ability to enhance data visualisation and uncover intricate patterns in extensive temporal datasets. The analysis utilized previously classified land use data from various time intervals, ensuring a consistent interpretation across all periods. The results of the change detection are displayed in both statistical tables and thematic maps, each with detailed legends to illustrate the shifts between different land use categories. To make things clearer and easier to understand, decadal land use change maps were created, allowing for a visual comparison of how land use has transformed over time, showcasing both gradual and sudden changes in the landscape.

a) Land Use Change From 1988 To 2000

Analysing the classified land use maps from 1988 and 2000 showed some significant changes in the different types of land cover within the Kitengela Conservation Area.

Riverine vegetation took a hit, dropping from 67.42 km² to 45.28 km², with a big chunk transforming into shrubland (19.93 km²) and grassland (14.14 km²), along with some minor shifts to cultivated land, bare land, water bodies, and artificial surfaces.

On the flip side, shrubland saw an increase, going from 249.34 km² to 286.85 km². While 172.16 km² stayed the same, it mostly expanded by taking over areas from grassland (92.66 km²) and riverine vegetation, even though it did lose some ground to other types. Grassland, however, shrank from 228.76 km² to 197.27 km², primarily converting into shrub land (92.66 km²), riverine vegetation, and artificial surfaces.

Cultivated land had a slight uptick, rising from 1.89 km² to 2.60 km², gaining space from grassland, bare land, and riverine vegetation, although most of the original cultivated land had already changed. Lastly, bare Land grew from 38.85 km² to 53.76 km², gaining ground from grassland and shrub land, but only 19.19 km² of the original area remained untouched.

Water bodies experienced a small decline from 0.37 km² to 0.36 km², with most of that area shifting to artificial surfaces, grassland, and other land uses, while artificial Surfaces nearly doubled, jumping from 2.74 km² to 5.26 km², mainly due to conversions from riverine vegetation, grassland, and bare land (Table 4.5).

Table 4.5 Land use change statistics for the period 1988-2000

Change detection statistic		**Area in sq. km of the classified map 2000**							
Classified map for the year 1988	**Land use**	**Riverine Vegetation**	**Shrub land**	**Grass land**	**Cultivated Land**	**Bare land**	**Water bodies**	**Artificial surfaces**	**TOTAL**
	Riverine vegetation	32.76	19.93	14.14	0.19	0.11	0.13	0.16	67.42
	Shrubland	5.02	172.16	38.39	0.63	32.35	0.03	0.76	249.34
	Grassland	2.55	92.66	128.6	0.96	1.35	0.12	2.52	228.76
	Cultivated land	0.13	0.00	0.23	0.81	0.72	0.00	0.00	1.89
	Bare land	1.82	1.97	14.88	0.00	19.19	0.00	0.99	38.85
	Water bodies	0.05	0.06	0.09	0.00	0.00	0.08	0.09	0.37
	Artificial surface	0.93	0.07	0.94	0.01	0.05	0.00	0.74	2.74
	TOTAL	43.26	286.85	197.27	2.60	53.76	0.36	5.26	589.36

b) Land Use Change from 2000 to 2010

A comparative analysis of land use maps from 2000 and 2010 shows some pretty significant changes in land cover throughout the Kitengela Conservation Area.

Riverine vegetation saw a slight increase, going from 43.26 km² to 45.28 km², even though there were conversions totaling 14 km² to shrub land, grassland, cultivated land, and artificial surfaces. In fact, only 29.26 km² of the original cover stayed the same.

On the other hand, shrubland took a hit, dropping from 286.85 km² to 250.31 km². While 161.92 km² was still intact, there were notable shifts to grassland (68.13 km²), bare land (49.23 km²), and artificial surfaces. Grassland also shrank, decreasing from 197.27 km² to 182.09 km², with significant losses to shrub land (71.15 km²) and riverine vegetation (12.76 km²), while seeing some growth in cultivated and artificial areas.

Cultivated land made a noticeable leap, increasing from 2.60 km² to 9.36 km². Even though it only retained 0.48 km² of its original area, it expanded mainly by converting bare land and artificial surfaces while bare Land grew from 53.76 km² to 89.67 km². Although 37.19 km² remained unchanged, it gained ground from shrub land, cultivated land, and artificial surfaces.

Water bodies experienced a slight decline, dropping from 0.36 km² to 0.35 km², with minor shifts to bare land, shrub land, and artificial surfaces. Finally, Artificial Surfaces saw a significant increase, expanding from 5.26 km² to 12.30 km², gaining area from cultivated land, grassland, shrub land, and bare land (Table 4.6).

Table 4.6 Land use change statistics for the period 2000-2010

Change detection statistics		**Area in sq. km of the classified map 2010**							
	Land use	**Riverine Vegetation**	**Shrub land**	**Grass land**	**Cultivated Land**	**Bare land**	**Water bodies**	**Artificial surfaces**	**TOTAL**
Classified map for the year 2000	Riverine vegetation	29.26	7.74	4.46	1.32	0.09	0.02	0.37	43.26
	Shrubland	3.14	161.92	68.13	1.47	49.23	0.01	2.95	286.85
	Grassland	12.76	71.15	105.96	1.62	1.13	0.04	4.61	197.27
	Cultivated land	0.03	0.23	0.03	0.48	1.83	0.00	0.00	2.60
	Bare land	0.03	8.99	3.14	3.02	37.19	0.03	1.36	53.76
	Water bodies	0.01	0.02	0.00	0.00	0.07	0.25	0.01	0.36
	Artificial surface	0.05	0.26	0.37	1.45	0.13	0.00	3.00	5.26
	Total	45.28	250.31	182.09	9.36	89.67	0.35	12.30	589.36

c) Land Use Change from 2010 to 2020

An analysis of land use maps from 2010 and 2020 showed some significant changes in land cover within the Kitengela Conservation Area. Riverine vegetation took a hit, dropping from 45.28 km² to just 26.92 km². Only 20.58 km² of this remained untouched, with a notable shift towards grassland (18.10 km²), artificial surfaces (2.67 km²), and cultivated land (1.55 km²).

Shrubland also faced a considerable decline, going from 250.31 km² to 191.53 km². A mere 114.77 km² stayed the same, while large portions transformed into bare land (59.96 km²), grassland (61.82 km²), and artificial surfaces (9.44 km²). Grassland saw a slight dip, decreasing from 182.09 km² to 180.60 km². While 91.39 km² remained, much of the rest shifted to shrub land (53.80 km²), bare land (17.60 km²), and artificial surfaces (14.95 km²).

On the other hand, cultivated land made a notable leap from 9.36 km² to 15.81 km², even though only 6.05 km² was preserved. This growth mainly came from conversions of bare land and grassland, while bare land surged sharply, increasing from 89.67 km² to 129.31 km². Only 51.28 km² stayed the same, with significant contributions from shrub land (20.39 km²), grassland (7.45 km²), and cultivated land (4.24 km²).

Water bodies remained relatively stable, with a slight increase from 0.35 km² to 0.38 km². Most changes were minor, involving shifts to and from bare land, shrubland, and cultivated land. Artificial surfaces saw a dramatic rise, expanding from 12.30 km² to 44.81 km². While

11.04 km^2 remained unchanged, there were significant new developments on land that was previously grassland (14.95 km^2), shrub land, and bare land (Table 4.7).

These changes highlight a concerning trend of vegetation loss, especially in riverine, shrub land and grassland areas, more bare ground, and a rise in human-made surfaces, pointing to growing human impact and ecological decline during the period.

Table 4.7 Land use change statistics for the period 2010-2020

Change detection statistics		**Area in sq. km of the classified map 2020**							
Classified map for the year 2010	**Land use**	**Riverine Vegetation**	**Shrub land**	**Grass land**	**Cultivated Land**	**Bare land**	**Water bodies**	**Artificial surfaces**	**TOTAL**
	Riverine vegetation	20.58	2.21	18.1	1.55	0.1	0.07	2.67	45.28
	Shrubland	2.74	114.77	61.82	1.55	59.96	0.03	9.44	250.31
	Grassland	2.15	53.8	91.39	2.1	17.6	0.1	14.95	182.09
	Cultivated land	1.39	0.24	1	6.05	0.28	0	0.4	9.36
	Bare land	0.02	20.39	7.45	4.24	51.28	0	6.29	89.67
	Water bodies	0	0.04	0.03	0.04	0.04	0.18	0.02	0.35
	Artificial surface	0.04	0.08	0.81	0.28	0.05	0	11.04	12.3
	Total	26.92	191.53	180.6	15.81	129.31	0.38	44.81	589.36

4.2 Relationship Between Migratory Wild Ungulates, Land Use Changes, And Human Population Dynamics from 1988-2020

An in-depth analysis of long-term trends in migratory ungulate populations, specifically wildebeest (*Connochaetes taurinus*) and plains zebra (*Equus quagga*) in relation to land use dynamics and human population growth in the Kitengela Conservation Area, revealed substantial and statistically significant patterns over the 32 years from 1988 to 2020. This analysis aimed to assess the extent to which habitat transformation and increasing anthropogenic pressure have influenced wildlife movements and population trajectories in the broader Nairobi National Park ecosystem.

During this period, the human population in Kitengela rose sharply from approximately 6,548 individuals in 1989 to 154,436 in 2019, an increase of over 2,250%. This demographic expansion coincided with rapid urbanisation and proximity to Nairobi. Kitengela lies along major transport routes connecting Nairobi to southern Kenya, making it attractive for residential development, commercial activities, and informal settlements. The landscape transitioned significantly, with formerly contiguous open rangelands increasingly fragmented by Artificial surfaces, cultivated plots, and bare patches resulting from soil degradation and land clearance. Grasslands and shrublands, which historically supported migratory corridors and forage availability for wild herbivores, were among the most impacted land cover types.

In tandem with these transformations, populations of wildebeest and zebra experienced marked declines. Wildebeest numbers fell from 2,706 individuals in 1990 to just 204 in 2019, despite a temporary peak of 5,157 in 1996. Human settlements and livestock grazing within the dispersal area increased after the year 2000, and this has limited the movements of wildebeest and other plains game species to and from the park (Owino *et al.,* 2011). Plains zebra populations exhibited a similar declining pattern, decreasing from 1,894 individuals in 1990 to 742 in 2019 (Owino *et al.,* 2011; KWS, 2020). The timing of these population decreases strongly coincided with periods of intensified land use change and human population growth, suggesting a close ecological link between habitat alteration and wildlife decline (Figure 4.2).

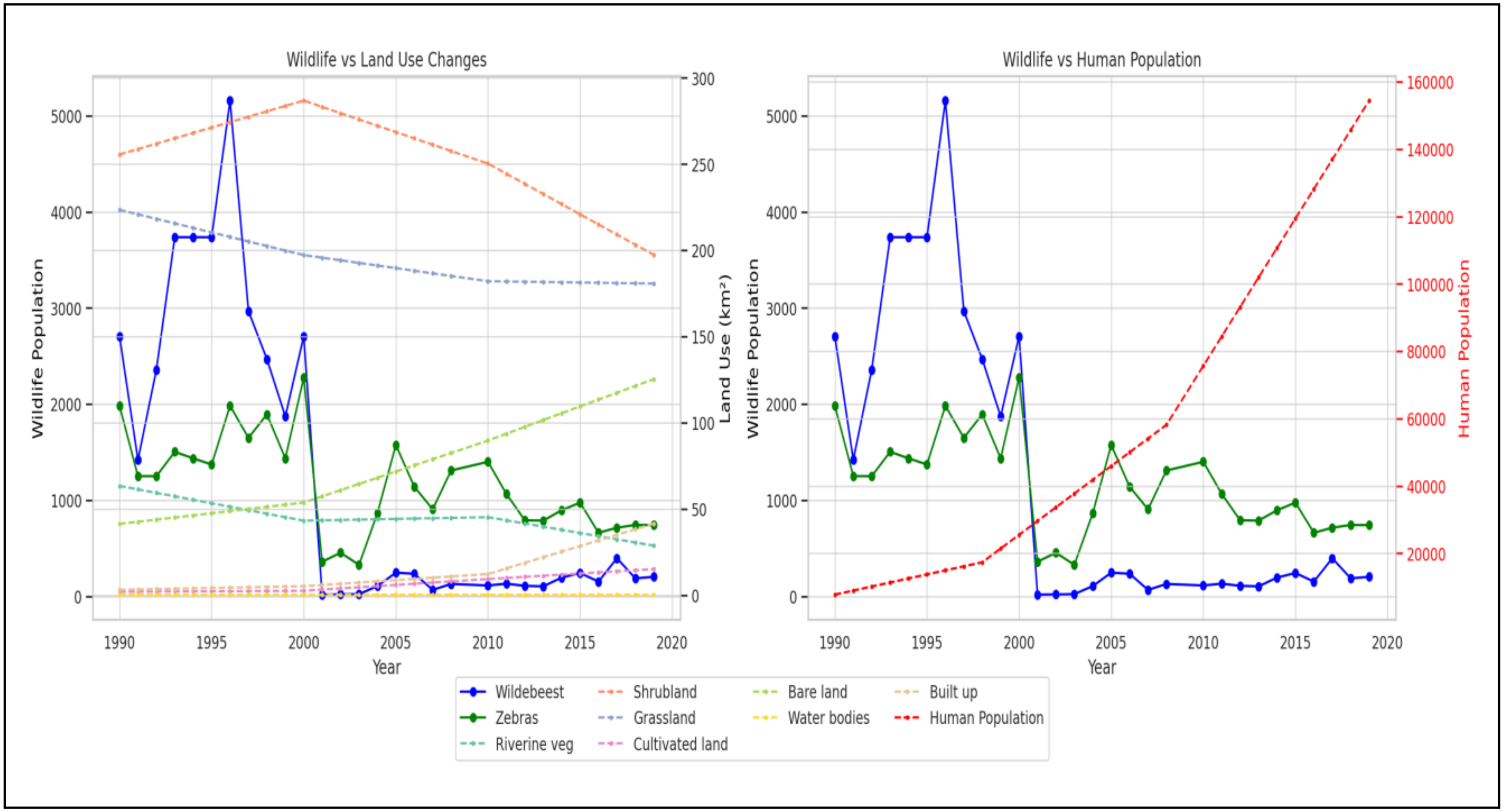

Figure 4.2 Annual changes in land use, human population size, and wildebeest and zebra populations in Kitengela between 1990 and 2019.

To statistically examine these associations, Spearman's rank correlation analysis was employed. This non-parametric method revealed strong positive correlations between wildebeest and zebra populations and the extent of grassland and riverine vegetation, both of which are essential for forage and water availability. Wildebeest abundance was moderately correlated with riverine vegetation ($\rho = 0.51$, $p = 0.004$) and grassland cover ($\rho = 0.54$, $p = 0.002$), while zebra populations demonstrated even stronger associations with the same land cover types ($\rho = 0.68$ and 0.62, respectively; $p < 0.001$ for both). These findings reaffirm the importance of maintaining continuous grassland and riparian habitats as core components of migratory ungulate ecology.

Conversely, both species showed statistically significant negative correlations with cultivated land, bare land, and artificial surfaces. For wildebeest, all three anthropogenic land use types had identical negative correlation coefficients ($\rho = -0.54$, $p = 0.002$), while zebra populations exhibited even stronger negative correlations ($\rho = -0.62$, $p < 0.001$). These results strongly suggest that expansion of agricultural activities, urban settlements, and physical infrastructure is associated with habitat fragmentation, blockage of migratory routes, and resource competition, ultimately contributing to the decline of migratory ungulate populations.

Other land cover classes exhibited less consistent relationships. Shrubland had a weak, non-significant positive correlation with wildebeest ($\rho = 0.19$, $p = 0.305$), but showed a modest significant correlation with zebra ($\rho = 0.42$, $p = 0.022$), possibly reflecting opportunistic habitat use by the latter. Water bodies had a marginally non-significant positive correlation with wildebeest ($\rho = 0.35$, $p = 0.056$), and a non-significant negative correlation with zebra ($\rho = -0.17$, $p = 0.376$) (Table 4.8). These results suggest that water availability may be seasonally important for wildebeest but is not a dominant driver of population dynamics over the long term.

Table 4.8 Spearman's rank correlation coefficients between migratory ungulate populations and land use classes (1988–2020).

Land Use Type	**Wildebeest (ρ)**	**p-value**	**Zebra (ρ)**	**p-value**
Riverine vegetation	0.51	0.004	0.68	<0.001
Shrubland	0.19	0.305	0.42	0.022
Grassland	0.54	0.002	0.62	<0.001
Cultivated land	-0.54	0.002	-0.62	<0.001
Bare land	-0.54	0.002	-0.62	<0.001
Water bodies	0.35	0.056	-0.17	0.376
Artificial surfaces	-0.54	0.002	-0.62	<0.001

Further analysis assessed the relationship between human population growth and ungulate abundance. A statistically significant negative correlation was observed between human population size and wildebeest numbers ($\rho = -0.54$, $p = 0.002$), as well as zebra populations ($\rho = -0.60$, $p < 0.001$). These inverse associations highlight the extent to which increasing human presence through habitat encroachment, infrastructure development, and land privatisation can exert pressure on migratory wildlife populations. In contrast, the strong positive correlation between wildebeest and zebra populations ($\rho = 0.75$, $p < 0.001$) underscores the shared ecological requirements and synchronized responses of these species to environmental stressors, such as habitat fragmentation, loss of forage continuity, and restricted migratory pathways (Table 4.9).

Table 4.9 Spearman's rank correlation coefficients between human population and migratory ungulate populations (1988–2020)

Pair	Spearman's ρ (r)	p-value
Human vs. Wildebeest Population	-0.54	0.002
Human vs. Zebra Population	-0.60	<0.001
Wildebeest and Zebras	+0.75	<0.001

Collectively, these findings underscore the adverse impacts of land use conversion and rapid human population expansion on migratory wild ungulates in the Nairobi National Park–Kitengela ecosystem. They highlight the urgent need for integrated land use planning, enforcement of conservation buffers, and restoration of critical migratory corridors to safeguard the future of wildlife populations in this rapidly urbanising landscape.

4.3 Socio-Demographic Characteristics of The Respondents and Their Implications on Community Perceptions on Land Use Changes and Their Impacts on Wild Ungulates

This section presents the socio-demographic profile of the 110 respondents from selected households in the study, achieving a 100% response rate. Key attributes assessed include gender, age, education level, duration of residence, and economic activity. Table 4.10 summarizes these characteristics together with the results of chi-square (χ^2) goodness of fit tests used to determine whether observed distributions significantly deviated from a uniform distribution.

A majority of respondents were male (56.4%), followed by females (42.7%), and a small proportion identified as intersex (0.9%). The gender distribution showed a statistically significant difference from an even distribution ($\chi^2 = 78.84$, df = 2, $p < 0.001$).

Regarding age, the largest group of respondents was aged 51–60 years (50.9%), followed by those aged 31–40 years (19.1%), 41–50 years (17.3%), above 60 years (8.2%), and 18–30 years (4.5%). This distribution was significantly skewed toward older age groups ($\chi^2 = 82.16$, df = 4, $p < 0.001$), indicating that the majority of respondents were older and potentially more experienced with land use changes in the area.

In terms of educational attainment, 40.0% had completed secondary education, 30.9% had primary education, and 19.1% had college education. A smaller proportion had no formal education (7.3%), while only 2.7% had attained university education. The educational distribution also showed significant variation ($\chi^2 = 43.45$, df = 4, $p < 0.001$).

The length of residence revealed that 59.1% of the respondents had lived in the area for over 20 years, 35.5% had stayed for 10–20 years, 4.5% for 5–10 years, and 0.9% had lived there for less than 5 years. This indicates a high proportion of long-term residents ($\chi^2 = 75.45$, df = 3, $p < 0.001$), which strengthens the credibility of their perspectives on land use dynamics.

Economically, the majority of respondents were engaged in business (62.2%), followed by pastoralism (27.0%) and formal employment (10.8%). This economic activity distribution was also significantly different from a uniform pattern ($\chi^2 = 46.25$, df = 2, $p < 0.001$), suggesting that business activities are dominant in the study area, likely reflecting local land use and economic shifts.

These findings provide important context for understanding how demographic factors may influence community perceptions and experiences regarding land use changes and their impacts on wild ungulates in the Kitengela ecosystem by performing a chi-square test of independence.

Table 4.10 Socio-demographic characteristics of respondents

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	62	56.4
	Female	47	42.7
	Intersex	1	0.9
Age group (years)	18–30	5	4.5
	31–40	21	19.1
	41–50	19	17.3
	51–60	56	50.9
	>60	9	8.2
Education level	None	8	7.3
	Primary	34	30.9
	Secondary	44	40.0
	College	21	19.1
	University	3	2.7
Years in area	<5	1	0.9
	5–10	5	4.5
	10–20	39	35.5
	>20	65	59.1
Economic activity	Pastoralism	30	27.0
	Business	68	62.2
	Formal employment	12	10.8

4.3.1 Drivers of Land Use Changes in Kitengela Conservation Area

To understand drivers of land use changes in the Kitengela Conservation Area, some descriptive statistics were conducted to understand how often each factor was reported. The study pinpointed a few key drivers of land use change in the region, with population growth (90%), agricultural expansion (51.8%), and urbanisation (39.1%) being the most cited drivers. These trends highlight a shift from traditional pastoralism to more permanent settlements and intensified farming, largely fueled by the growing pressure of new residents and the area's closeness to Nairobi. Other factors that played a role included changes in land tenure policy (15.5%), economic incentives (8.2%), and less frequently mentioned environmental stressors like climate change, fire, and mining. These findings emphasize that human activities are the main forces reshaping land use in this area **(**Figure 4.3).

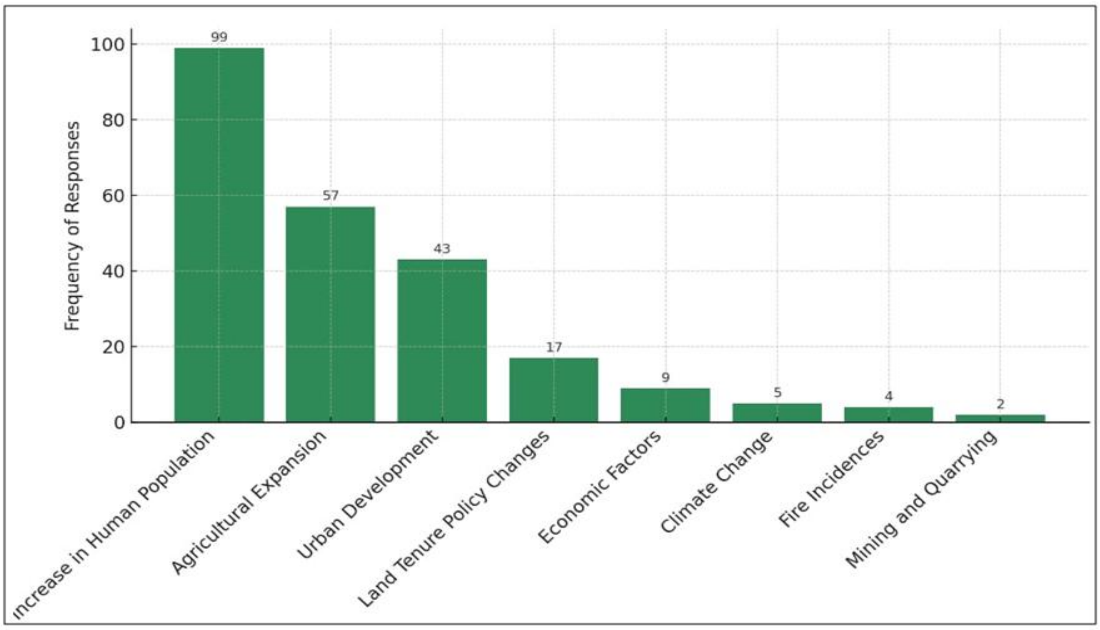

Figure 4.3 Perceived drivers of land use changes in the Kitengela conservation area.

Note: The total percentage exceeds 100% because respondents select multiple drivers.

To determine if the differences in how people perceive the drivers of land use change were statistically significant, a chi-square goodness-of-fit test was conducted. Results ($\chi^2 = 279.62$, df = 7, $p < 0.001$) showed a significant difference, which suggested that all drivers were not cited equally. This finding reveals that respondents had a clear preference for certain drivers over others when it comes to land use changes. Notably, the increase in human population and agricultural expansion emerged as the most significant factors.

4.3.2 Influence of Demographic Characteristics on Perception

Chi-square tests of independence were performed across five variables: gender, age, education level, years lived in the area, and main economic activity to determine if perceptions of the respondents were influenced by their socio-demographic characteristics. Results showed that years lived in the study area by respondents had a statistically significant link to how they perceived the drivers of land use changes in the area ($\chi^2 = 51.0$, df = 15, $p < 0.001$). This implies that typical residents have different opinions from the immigrants regarding drivers of land use changes in Kitengela (Table 4.11).

Table 4.11 Chi-Square Test Results for Demographic Variables vs. Perceived Drivers of Land Use Changes

Demographic Variable	**Chi-square (χ^2)**	**df**	**p-value**
Gender	3.7	10	0.96
Age	18.7	20	0.54
Education level	14.9	20	0.78
Years lived in the area	51.0	15	**< 0.001**
Main economic activity done	22.1	15	0.11

A contingency table was created to highlight perceived drivers of land use changes based on respondents' residency in the study area. The distribution showed that human population growth and expansion of agriculture were often highlighted as the main factors, particularly by those who have been living in the area for more than 20 years. Respondents who had resided in the study area for 10 to 20 years, as well as those of over 20 years, viewed urbanisation in a similar light. On the other hand, factors like economic issues, climate change, wildfires, and mining or quarrying received less attention overall (Figure 4.4).

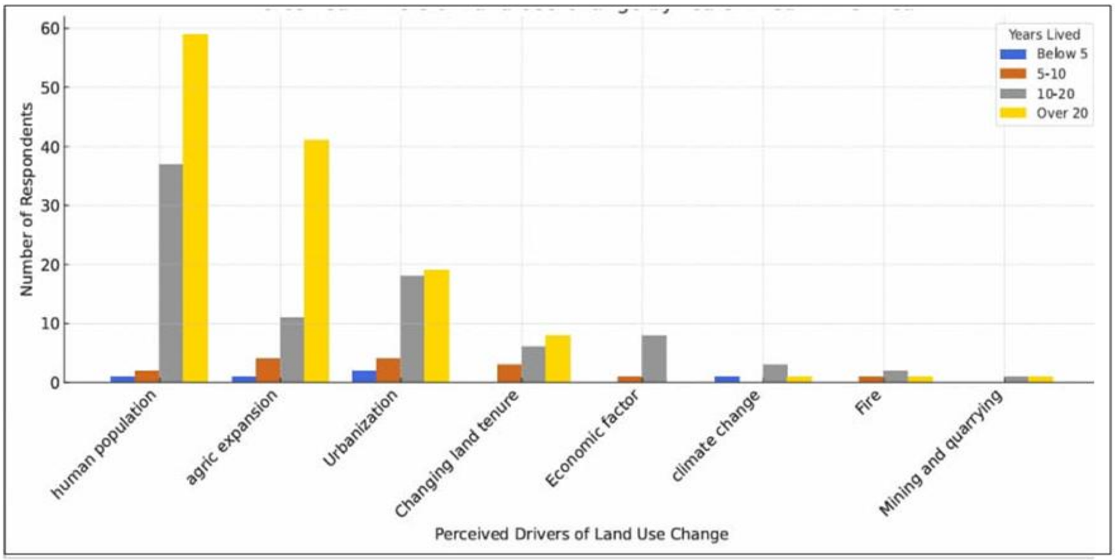

Figure 4.4 Perceived Drivers of Land Use Change by Years Lived in the Area

4.4 Impacts of Land Use Changes on Habitat, Mortality, and Behaviour of Wild Ungulates

To understand how changes in land use affect the habitat, mortality and behaviour of wild ungulates in the Nairobi National Park ecosystem, impacts cited were categorized into three main themes: habitat-related (ecological), mortality-related (anthropogenic), and behavioral impacts according to the objective. Each type of impacts was analyzed using descriptive statistics and comparative insights drawn from the relative importance of responses within and across these categories.

Habitat-related impacts were the most reported issue, with a total of 250 responses, out of which habitat fragmentation was the most highlighted by 101 respondents (40.4%), followed closely by physical alterations to the environment (34.8%) and habitat loss (24.8%).

Regarding mortality-related impacts, 61 responses were recorded, of which road mortality accounted for 43 (70.5%) and construction-related mortality for 18 (29.5%).

Lastly, out of 60 respondents who addressed behavioural impacts, the most frequently reported concern was modification of animal behavior, cited by 32 respondents (53.3%), followed closely by increased human use of traditional wildlife areas, noted by 28 respondents (46.7%). (Table 4.12).

Table 4.12 Perceived Impacts of Land Use Changes on Migratory Wild Ungulates

Thematic Category	**Impact Type**	**Frequency**	**Percentage (%)**
Habitat (Ecological)	Habitat fragmentation	101	91.8
	Habitat loss	87	79.1
	Physical alteration	62	56.4
Subtotal		**250**	**67.4**
Mortality	Road mortality	43	39.1
	Construction mortality	18	16.4
Subtotal		**61**	**16.4**
Behavioural	Animal behaviour changes	32	29.1
	Increased human presence	28	25.5
Subtotal		**60**	**16.2**

Note: The total percentage exceeds 100% because respondents were allowed to select multiple perceived impacts.

4.4.1 Comparative Perceptions among Impact Categories

From thematic categories, it is evident that habitat-related impacts (n = 250) were viewed as the most urgent threats to migratory wild ungulates, followed by mortality-related impacts (n = 61) and behavioural impacts (n = 60). This order suggests that local stakeholders are more concerned about ecological degradation and habitat loss than other types of impacts. The results also showed that people are more likely to notice physical changes in the landscape compared to indirect or delayed effects, such as mortality and changes in behavior.

To statistically determine significant differences in the perceptions of impacts of land use changes on wild ungulates, Chi-square goodness-of-fit test was used. Results (χ^2 = 193.49, df = 2, p <0.001) showed significant differences, which suggested that all impacts were not cited equally. This finding reveals that respondents had a clear preference for certain impacts over others, where habitat-related impacts were mostly perceived by the respondents.

4.4.2 Influence of Demographic Characteristics on Respondents' Perceptions on Impacts of Land Use Changes

To determine if perceptions of the respondents were affected by demographic characteristics of respondents, chi-square tests of independence were performed across five variables: gender, age, education level, years lived in the area, and main economic activity undertaken. Results (χ^2 = 17.3, df = 8, p = 0.03) showed that only the level of education had a statistically significant link to how respondents perceived the type of impact. This implies that a person's educational background might shape their views on how land use changes affect wild ungulates, whether through habitat degradation, increased mortality, or changes in behavior. On the other hand, no significant connections were found regarding gender, age, years of residence, or primary economic activity, suggesting that these factors didn't notably influence how people perceived the type of impact (Table 4.13).

Table 4.13 Chi-square test results for demographic variables versus perceived impact category

Demographic Variable	**Chi-square (χ^2)**	**df**	**p-value**
Gender	0.8	4	0.94
Age	9.0	8	0.34
Education Level	17.3	8	**0.03**
Years lived in the area	3.3	6	0.77
Main economic activity done	3.9	4	0.42

A contingency table created to highlight perceived impacts of land use changes based on education level showed that habitat impacts were the most frequently mentioned across all education levels, especially among individuals with secondary (36.4%) and primary education (30.9%). Only a small fraction of college-educated respondents (3.6%) acknowledged behavioural impacts, while those with secondary education (3.6%) also pointed out mortality impacts. This trend supports the statistical findings from the chi-square test, suggesting that education might shape how people understand and prioritize ecological versus human-related or behavioral impacts on wildlife (Figure 4.5).

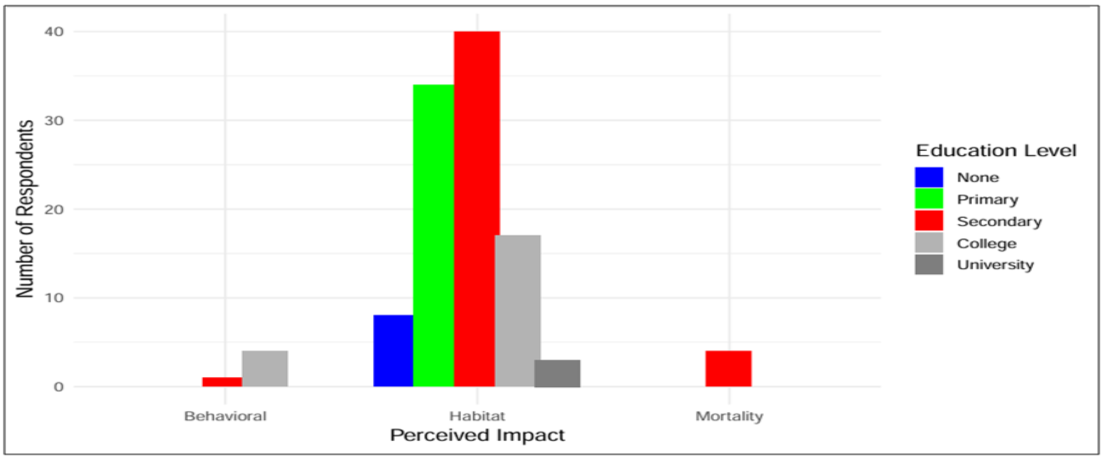

Figure 4.5 Influence of education level on the respondents' perceived impacts of land use change

4.5 Insights from Key Informant Interview

Key informant interviews with stakeholders from KWS, NEMA, NGOs, group ranches, and Kitengela CBOs revealed consistent concerns over land use change in Kitengela. Most agreed that land ownership has shifted toward privatization and fragmentation, leading to a decline in open rangelands. KWS and NGO (African Wildlife Foundation) representatives reported disruptions to migratory routes due to fencing, cultivation, and urban development, which have contributed to increased human-wildlife conflict.

NEMA respondents noted that while Environmental Impact Assessments (EIAs) are required for new developments, enforcement of recommendations remains weak. They also raised concerns about the ecological risks posed by informal settlements near Nairobi National Park. Community-based organisations highlighted population growth, land subdivision, and economic pressures as key drivers of land transformation, resulting in reduced grazing areas and wildlife presence.

Overall, the KIIs confirmed the major trends identified in quantitative data and emphasised the need for integrated land use planning, stronger enforcement mechanisms, and greater community engagement in conservation efforts.

4.6 Results from Field Observations

Field observations have uncovered a variety of land use activities within the Kitengela conservation area that are having a significant impact on the movement and habitat of migratory wild ungulates. Among the most notable activities are the fencing of individual land parcels, the growth of industries, the rise of urban centres, and mining operations. All of these factors contribute to landscape fragmentation, making it harder for wildlife to access their traditional migratory routes.

The foregoing findings are backed up by photographic evidence (Figures 4.6 to 4.12), which illustrate the extent of the land use changes observed during the field survey. One major concern is the waste disposal at the Kitengela dumpsite, which poses an increasing threat not just to the health and well-being of residents but also to migratory species like wildebeest and zebras that often visit the area. This site highlights how poor land use practices can create ecological barriers and put wildlife at risk, exposing them to dangers like ingesting non-biodegradable materials and contaminating their grazing grounds (Figure 4.6).

Figure 4.6 Kitengela dumping site located within the wildlife corridor.

(Source: Author, 2022)

The mining of stone, sand, and soil in the Kitengela wildlife corridor has had a major impact on the local habitat, making large areas of the landscape unfit for wildlife to live and thrive. Open-pit quarries and extraction sites disrupt the natural vegetation and change the physical landscape, which in turn reduces the availability of crucial resources like food and water (Figure 4.7).

Additionally, these exposed quarries create physical obstacles and safety risks that hinder the movement of migratory wildlife, especially wildebeest and zebras. Their seasonal migrations are vital for reaching scattered grazing areas and keeping the population dynamics in balance throughout the ecosystem.

Figure 4.7 Stone quarry located within Kitengela wildlife corridor

(Source: Author, 2022)

Perimeter walls (Figure 4.8) that enclose sizable pieces of land within the Kitengela wildlife corridor were also a common feature. These permanent fencing structures act as significant obstacles to wildlife movement, especially for migratory species like wildebeest and zebras. By fragmenting natural habitats, limiting access to essential resources, and disrupting traditional migratory routes, these fences contribute to declining populations and heightened human-wildlife conflicts.

Figure 4.8 Wildlife-proof fencing for a private farm within the Kitengela migratory corridor

(Source: Author, 2022)

Another feature that was common in the study area was barbed wire fencing (Figure 4.9) that marked out individual land parcels. While these fencing systems are less intrusive than solid perimeter walls, they still create significant challenges for migratory wildlife. These fences can hinder movement, lead to injuries, and break up habitats, which is especially problematic for species like wildebeest and zebras that depend on seasonal migrations to find grazing and water sources.

Figure 4.9 private farm fence to deter migratory wildlife within Kitengela migratory corridor.

(Source: Author, 2022)

Development of hotels and lodges (Figure 4.10) was also observed in the Kitengela wildlife corridor. While these projects boost tourism and economic growth, they also lead to habitat fragmentation and an increase in human activity within the ecosystem. This growth disrupts the natural migratory paths of wildlife, limiting their movement and changing their behaviors, which ultimately puts their survival at risk.

Figure 4.10 KenPipe Garden Hotel constructed within the Kitengela corridor.

(Source: Author, 2022)

Another driver of land use change in the Kitengela conservation area is infrastructure development. Figure 4.11 shows the Standard Gauge Railway (SGR) line cutting through the Kitengela wildlife corridor. Building such linear structures really breaks up natural habitats and puts up obstacles for migratory animals. This not only restricts their access to essential resources but also disrupts their seasonal movements, leading to long-term ecological issues for wildlife conservation in the region.

Figure 4.11 Standard Gauge Railway cutting across the Kitengela corridor.

(Source: Author, 2022)

The swift growth in industrial activities has resulted in more human encroachment, which in turn has led to habitat fragmentation, degradation, and loss. These changes in land use present serious risks to the integrity of the corridor by diminishing connectivity and disrupting the migratory routes of wildlife (Figure 4.12**)**.

Figure 4.12 Cement factory constructed within the Kitengela corridor.

(Source: Author, 2022)

CHAPTER FIVE

DISCUSSION

5.1 Land Use Changes in Kitengela Conservation Area

This study found that the Kitengela wildlife migratory corridor and dispersal area underwent substantial land use change between 1988 and 2020. Analysis of Landsat satellite imagery showed a progressive transformation of the landscape into settlement zones, with artificial surfaces, bare land, and cultivated land becoming increasingly dominant. During this period, most of the area has been increasingly transformed into settlement zones, with artificial surfaces, bare land, and cultivated fields leading as the primary land uses. The most rapid changes occurred between 2010 and 2020, during which artificial surfaces and water bodies increased sharply, while riverine vegetation and shrubland declined considerably. These findings point to accelerated landscape transformation within the ecosystem and suggest increasing pressure on wildlife habitats and movement routes.

The observed pattern is consistent with broader evidence from pastoral and peri-urban landscapes, where changing livelihood strategies and socio-economic pressures have encouraged a shift from traditional pastoralism to crop cultivation and permanent land use forms (Lynn, 2010). Similar studies have shown that such transitions reduce available rangelands, fragment habitat, and compress wildlife dispersal spaces, thereby constraining the movement of migratory ungulates (Kauffman *et al.*, 2021). In the Kitengela ecosystem, these changes appear to have significantly reduced the ecological functionality of the migratory corridor and dispersal area.

The decrease in water bodies between 1988 and 2010 highlighted the siltation and degradation of dams and water pans that were established back in the 1980s. However, an increase between 2010 and 2020 may be explained by the construction of additional dams, such as the Mbagathi Dam and water pans, after earlier periods of degradation and siltation (Morara *et al.*, 2014). Increased water availability is likely to influence the abundance, distribution, and seasonal movement of both wildlife and livestock in the area (Kija *et al*., 2020). This suggests that while some land use changes may temporarily improve access to water, the broader pattern of habitat conversion still poses major ecological risks because it is occurring alongside vegetation loss and increasing human encroachment.

The findings further showed that land use change closely mirrored rapid human population growth in the Kitengela Conservation Area. Population increase appears to have intensified demand for housing, infrastructure, schools, and food production, thereby driving the expansion of cultivated land and artificial surfaces. At the same time, this growth corresponded with substantial declines in riverine vegetation, shrubland, and grassland. This interpretation is in line with previous studies, which linked rising population density and peri-urban expansion to land subdivision, settlement growth, and the conversion of wildlife habitats into human-dominated land uses.

The study also established that the transition from communal to individual land ownership contributed to land fragmentation, particularly around Kitengela town, where land has increasingly been subdivided into smaller plots for sale and development. This process has intensified the conversion of wildlife dispersal areas into residential, commercial, and agricultural uses, thereby disrupting migratory routes used by wild ungulates. Similar patterns have been documented in earlier studies of the Kitengela-

Athi-Kapiti plains, which associated land privatisation and subdivision with corridor shrinkage, declining habitat quality, and increased human-wildlife conflict (Mathenge *et al.* 2020; Wandaka & Francis 2019).

5.2 Relationship Between Migratory Wild Ungulates, Land Use Changes, And Human Population Dynamics

This study found a clear relationship among changes in land use, human population growth, and the decline in migratory ungulates in the Kitengela conservation area. The results showed that increases in artificial surfaces, cultivated land, and human population were associated with declines in wildebeest and zebra populations, whereas natural land-cover classes that support forage, movement, and habitat continuity were reduced over time. Collectively, these findings indicate that landscape transformation and demographic pressure have contributed substantially to the decline of migratory ungulates in the study area.

The findings are consistent with previous studies showing that human population growth near wildlife dispersal areas often leads to habitat conversion, restricted movement, and increased competition over land and natural resources. Earlier research has similarly shown that as settlement, cultivation, and infrastructure expand into migratory landscapes, wildlife populations tend to decline because critical movement routes and grazing areas become fragmented or inaccessible (Crego *et al.*, 2021; Ogutu *et al.*, 2020). In this context, the observed decline in wildebeest and zebra populations reflects a broader pattern documented in migratory ungulate systems subjected to increasing anthropogenic pressure.

The significant positive correlations between wildebeest and zebra populations and intact grassland and riverine vegetation highlight the ecological importance of these habitats as critical grazing and watering zones. Over time, as agricultural and artificial surfaces expanded, these core habitats shrank and became fragmented, forcing ungulates to adjust their movement paths or face population declines. Similar relationships have been documented in other East African rangelands, such as Somali, Borana plateau, Maasai, Karamoja, and Northern Bah el Ghazal rangelands, where reduction of open grasslands through privatization and settlement expansion has been directly linked to reductions in wildlife biomass and migration continuity (Lind *et al.*, 2020). Similar findings have been reported from Tanzania's Tarangire ecosystem, where community conservation stabilizes ungulate populations (Bond *et al.,* 2022; Brehony *et al.*, 2022), and from the Serengeti–Mara migration tied to grass and river availability (Stabach *et al.*, 2022). Riverine corridors, often neglected in spatial planning, remain essential during dry seasons and drought periods, highlighting the need to safeguard these riparian zones.

Conversely, the strong negative correlations between ungulate populations and cultivated land, bare land, and artificial surfaces reflect widespread anthropogenic land conversion (Gichuru, 2022; Stabach *et al.,* 2022). In Kitengela, agricultural expansion and real estate development have progressively encroached into traditional dispersal areas, mirroring patterns observed in other wildlife corridors facing similar peri-urban pressures (Simkin *et al.,* 2022). These land transformations introduce physical barriers, such as fences and roads, which not only obstruct migration but also fragment habitats, reduce forage availability, and increase the likelihood of wildlife-vehicle collisions.

Shrubland and water bodies showed weaker or inconsistent relationships with ungulate populations. Shrubland, while moderately used by zebras, is generally less preferred by wildebeest. Water bodies, though essential, may vary seasonally and spatially, leading to non-significant statistical associations despite their functional importance. These findings reflect patterns also noted in studies assessing fine-scale habitat use among migratory ungulates under increasing landscape heterogeneity (Riggio *et al*., 2020). Maintaining open grassland-riverine mosaics and improving corridor permeability via fence removal and community efforts is critical for conserving migratory ungulates in East Africa (Schwandner *et al*., 2025).

Kitengela's human population grew dramatically by over 2,250% between 1989 and 2019, driving intense land competition and habitat loss, consistent with broader urbanisation trends in sub-Saharan Africa (Simkin *et al.*, 2022). This growth is strongly negatively correlated with wildebeest and zebra populations. Wildebeest, which rely on large, connected rangelands for seasonal migration, are vulnerable to habitat fragmentation and infrastructure development caused by expanding settlements (Cooke *et al.,* 2024; Hunninck, 2020; Roque, 2023; Stabach *et al.,* 2022). Zebras show an even stronger decline due to competition with livestock, fencing, and human-wildlife conflict, indicating that human pressures have exceeded their adaptability (Smith *et al.*, 2022). The positive correlation between wildebeest and zebra populations reflects their shared ecological needs and similar responses to environmental pressures, highlighting that ecosystem challenges such as urban development and livestock competition are reducing the landscape's capacity to support migratory grazers (Delaby *et al.*, 2020; Pozo *et al.*, 2021).

More broadly, global assessments emphasise that migratory herbivores are facing an era of reduced mobility due to increasing fencing, settlement, and infrastructure development across open landscapes. Studies mapping migratory pathways across continents from Mongolia to the Serengeti warn that the continuity of these ecological processes is under imminent threat without legal recognition and protection of migration corridors (Kauffman *et al.*, 2021).

In the specific context of Nairobi National Park and Kitengela, these findings point to the critical need for safeguarding and restoring key grassland and riparian habitats to maintain the ecological connectivity required for seasonal wildlife movements. Community-led conservancies, participatory spatial planning, and legal corridor demarcation are among the strategies increasingly advocated to prevent the collapse of migratory systems in urbanising regions (Ige *et al.*, 2024; Rytkönen & Hotakainen, 2020).

Overall, this study adds to a growing body of evidence indicating that without coordinated intervention, the ecological integrity of Kenya’s last peri-urban wildlife dispersal areas could be permanently compromised. Further, the findings from Kitengela provide timely insights to inform conservation planning and policy aimed at reconciling development and biodiversity conservation in rapidly transforming rangeland ecosystems.

From the foregoing discussion, study results have highlighted a well-known fact: human expansion and changes in land use are strongly associated with wildlife population declines in African rangelands, as stated by Assede *et al.* (2023). The Kitengela

Conservation Area is a prime example of how rapid demographic shifts can create fragmented landscapes that no longer meet the needs of migratory species.

Additionally, the strong connection between wildebeest and zebra populations suggests that conservation efforts need to be broad and integrated across species. Simply protecting isolated species in fragmented areas is unlikely to work without ensuring that there are ecological corridors and connections between Nairobi National Park and nearby dispersal zones.

Several studies have called for immediate reforms in land use to protect the remaining migratory routes. Løvschal *et al.* (2017) and Said *et al.* (2016) highlight the need to curb unregulated fencing and promote communal land use practices that keep rangelands open. In Kenya and Namibia, community-based conservancies, land tenure reforms, and payments for ecosystem services (PES) have shown potential as effective strategies for fostering harmony between pastoral communities and wildlife (Bedelian & Ogutu, 2017).

5.3 Drivers of Land Use Changes in the Kitengela Conservation Area

This study identified rapid human population growth as the leading driver of land use change in the Kitengela Conservation Area, followed by agricultural intensification and urbanisation. Other contributing factors included changes in land tenure systems, economic motivations, climate-related stress, fire, and extractive activities such as mining and quarrying. These findings show that land transformation in Kitengela is being driven primarily by human-induced socio-economic pressures rather than by natural processes alone. The Chi-square goodness-of-fit test showed that the frequency with which respondents mentioned the drivers of land use change differed significantly.

In particular, population growth resulting from migration into the area and agricultural expansion driven by increasing demand for food production were cited significantly more often than other factors, indicating that they are perceived as the dominant drivers shaping land use dynamics in Kitengela.

5.3.1 Human Population Growth

The common belief that land use changes are mainly due to population growth is backed by numerous studies throughout sub-Saharan Africa. These studies show a clear link between rising populations and the growing need for land for housing, infrastructure, and livelihoods (de Bruin *et al.*, 2021). In Kitengela, being close to Nairobi has attracted many people looking for affordable homes, business prospects, and better access to city amenities (Tarichia, 2022). This urban expansion has turned once-open pastoral lands into crowded peri-urban neighborhoods, resulting in land fragmentation and the transformation of wildlife corridors into permanent settlements (Albero, 2023).

5.3.2 Agricultural Expansion

Another key driver of land use change is agricultural expansion, driven by rising food demand from a growing population, resulting in a shift from traditional pastoralism to more intensive and permanent crop production. This shift is driven by a combination of population pressure, evolving land ownership patterns, and climate variability, all of which have reduced the sustainability of traditional livestock farming. (Mung'ong'o, 2022). People in Kitengela have noted that open communal lands are increasingly being fenced off and turned into smallholder farms. This trend mirrors findings from the Mara and Laikipia ecosystems, where similar developments have led to a decline in wildlife habitats and obstructed migratory routes (Babu, 2024; Kaua, 2023).

The expansion of agricultural land use also heightens conflicts between humans and wildlife, as animals venture into cultivated areas, leading to crop damage and retaliatory killings (Bosco & Sila, 2025). Additionally, the fencing that comes with agriculture has been particularly harmful to large migratory herbivores like wildebeest and zebra, whose seasonal movements are crucial for their survival (Owen-Smith *et al.*, 2020).

5.3.3 Urbanisation and Infrastructure Development

Urbanisation stands out as a major transformative force. The growth of infrastructure in Kitengela think roads, new housing developments, and commercial spaces, has fragmented habitats and limited wildlife movement. While this kind of development can certainly boost the economy, it also brings about irreversible changes to the environment (Nyumba *et al.,* 2021; Rees, 2021). The expansion of Nairobi city has effectively turned Kitengela into a commuter hub, with land use rapidly shifting to meet the demands of urban infrastructure (Mkonyi, 2021).

5.3.4 Changes in Land Tenure

Changes in land tenure, mentioned by 15.5% of respondents, have significantly impacted land use as well. Land subdivision and the issuance of individual title deeds in the Kitengela area began mainly in the late 1980s and intensified through the 1990s following the dissolution of Maasai group ranches (Wandaka & Francis, 2019). Privatization of land ownership enabled individual landholders to legally sell their parcels, which accelerated land transactions and attracted migrants and developers, ultimately driving rapid settlement growth and land use change in the region (Mugambi, 2022). This shift towards privatization has diminished the communal management practices that previously supported seasonal grazing and wildlife movement, leading to unsustainable land use and further fragmentation (Swette & Lambin, 2021).

This trend reflects broader patterns in pastoral regions of Kenya, where land titling, originally meant to secure rights, has instead sparked land commodification and fencing, particularly in high-value wildlife dispersal areas (Enns & Bersaglio, 2024).

5.3.5 Economic Incentives and Environmental Stressors

Although economic incentives and environmental stressors were cited less frequently, they are important drivers of land use change in Kitengela. Rising land values and real estate opportunities encourage landowners to sell or develop land, while climate variability, droughts, and extractive activities such as quarrying reduce the viability of traditional livestock grazing. Together, these factors accelerate habitat fragmentation and exacerbate pressure on wildlife dispersal areas, demonstrating that even less frequently mentioned drivers can have outsized ecological impacts when combined with population growth, agricultural expansion, and urbanisation.

Economic incentives play a significant role in driving land conversion, especially with the allure of land sales, real estate investments, and profits from horticulture. As Kitengela land becomes more valuable due to its closeness to Nairobi and key transport routes, many landowners are choosing to sell or develop their properties instead of keeping them for conservation purposes (Araka, 2021). This trend of monetizing land highlights the growing pressures of capitalism that increasingly undermine traditional conservation efforts (Spash, 2022).

Environmental stressors like climate change, mining, and fire were mentioned less frequently, but they are equally crucial factors in land use changes. Extended droughts and unpredictable rainfall have disrupted livestock production, pushing households to explore alternative land uses, often at the cost of wildlife-friendly livelihoods (Thapa & Tuladhar, 2021). Localized activities like quarrying and sand mining are contributing to soil degradation and loss of vegetation, which together impact land productivity and the presence of wildlife.

5.4 Impacts of Land Use Changes on Wild Ungulates in Nairobi National Park

This study found that land use changes in the Kitengela Conservation Area have substantially impacted migratory wild ungulates in Nairobi National Park, with habitat-related effects identified as the most dominant factor. Respondents most frequently identified habitat fragmentation, habitat loss, and alteration of the physical environment as the main consequences of land transformation. These impacts appear to have reduced the availability of continuous habitat needed for movement, feeding, and seasonal dispersal, thereby undermining the ecological function of the Kitengela dispersal area.

5.4.1 Habitat-Related Impacts

The study found that the most recognised impacts on habitats were related to fragmentation, physical changes to the environment, and habitat loss. This finding echoes the work of Ogutu *et al.* (2016), who noted that land subdivision and fencing in the Kitengela rangelands have disrupted migratory routes and diminished habitat connectivity. Habitat fragmentation has particularly hindered seasonal movements between Nairobi National Park and nearby dispersal areas, resulting in isolated wildlife populations and weakened ecological resilience (Mungai, 2022).

Moreover, the ongoing trend of urbanisation and infrastructure development has transformed traditional grazing lands into urban spaces (Acebes *et al.*, 2021). These changes not only shrink the available habitats but also degrade habitat quality due to edge effects, human disturbances, and the encroachment of invasive plant species (Mengist *et al.*, 2021). The findings of this study confirm that these habitat changes are not only noticeable but are also of concern to local stakeholders, indicating a rising worry about the ecological sustainability of the region.

5.4.2 Mortality-Related Impacts

Mortality-related impacts in the Kitengela Conservation Area, particularly roadkill and deaths from construction and fencing, are significant direct threats to migratory wildlife, even though they were cited less frequently than habitat loss. Similar patterns have been observed in the Tsavo Conservation Area, where long-term monitoring along the Nairobi–Mombasa Highway recorded over 1,400 wildlife roadkill incidents over 11 years (Lala *et al*., 2021), indicating that major transport corridors intersecting wildlife habitats pose substantial mortality risks. This study also concurred with a study by Chemwa *et al. (*2025) in Athi-Kapiti Plains, which also reported 218 roadkill incidents over four years, with fatalities clustering near water sources and riparian habitats. This aligns with our findings in Kitengela, suggesting that road location relative to critical habitats strongly influences wildlife mortality.

Deaths from construction and fencing were also found to cause mortality to wild ungulates in the area. This finding concurred with studies in Kajiado conservancies, which have found that fencing associated with agriculture and urban expansion leads to entrapment and fatalities among large mammals (RAMAT Wildlife Society, 2024). Likewise, Stabach et al. (2025) noted that fences disrupt large-scale ungulate migrations across East Africa, which agrees with our observation that Kitengela dispersal zones are increasingly obstructed, raising mortality risks for wildebeest and zebra.

Furthermore, research in the Serengeti-Mara ecosystem has demonstrated that construction and habitat fragmentation can elevate mortality even in relatively intact protected areas (Ogutu et al., 2016). This supports our conclusion that peri-urban landscapes like Kitengela, located near Nairobi, experience similar mortality pressures due to high traffic density, urban expansion, and rapid land use change.

Overall, these studies indicate that road infrastructure, fencing, and construction consistently contribute to wildlife mortality across East African ecosystems and that targeted mitigation measures such as wildlife crossings, regulated fencing, and environmental compliance in construction are critical to reduce direct human-caused fatalities in Kitengela and similar dispersal areas.

5.4.3 Behavioural Impacts

Behavioural impacts, including increased interactions between humans and wildlife and changes in animal movement or activity patterns, were strongly reported in this study. Similar patterns had been documented in a study by Ogutu *et al*. (2016) in Nairobi National Park, where human settlements encroaching on traditional dispersal zones of migratory wild ungulates have forced wildebeest, zebras, and other ungulates to alter their movement timing and routes.

Disturbances caused by noise, human presence, and land use changes trigger avoidance behaviours, stress-related hormonal changes, and altered migratory patterns (Gaynor et al., 2018). Similar behavioral responses have also been observed in other East African rangelands, where ungulates avoid areas with high human activity, roads, and livestock, leading to uneven grazing pressure and potential habitat degradation (Thaker et al., 2011).

An important finding in this study is that education level significantly influenced how respondents perceived the impacts of land use change, while gender, age, duration of residence, and economic activity did not show significant associations. This suggests that differences in knowledge or environmental awareness may shape how people interpret ecological change, especially in distinguishing habitat, mortality, and behavioural effects on wildlife. Even so, the strong overall emphasis on habitat-related impacts across respondent groups reinforces the central conclusion that land use change is primarily undermining wildlife persistence through habitat fragmentation and loss of connectivity.

Overall, the findings demonstrate that land use changes in the Kitengela dispersal area are not only altering the physical landscape but are also weakening the ecological relationship between Nairobi National Park and its surrounding seasonal range. This has serious implications for the long-term conservation of migratory ungulates because the survival of these species depends on continued access to connected habitats beyond the park boundary. The results therefore highlight the need for stronger protection of dispersal areas, control of unplanned development, and restoration of habitat connectivity within the NNP–Kitengela ecosystem.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings of this study, several key conclusions are drawn:

i. **Land use transformations in Kitengela (Objective i)**

Analysis of Landsat satellite imagery revealed extensive land use changes in the Kitengela conservation area from 1988 to 2020, with a transformation rate of 61.4%. Open rangelands, riverine vegetation, and shrublands have largely been converted into cultivated land, bare land, and artificial surfaces. Urban, industrial, and agricultural developments have expanded significantly, indicating that land use in the area is undergoing rapid and ongoing transformation. This suggests that at current rates, functional wildlife corridors may be completely severed within 15-20 years, requiring immediate county-level land use zoning interventions.

ii. **Impact of human population growth on migratory ungulates (Objective ii)**

Rapid human population growth, primarily due to migration from Nairobi and surrounding areas, has exerted strong pressure on the Kitengela ecosystem. This growth has disrupted the abundance, survival, and movement of migratory ungulates such as wildebeests and zebras, compressed their traditional dispersal zones, and obstructed seasonal migration routes. This implies that without urgent population-sensitive planning, the ecological functionality of Nairobi National Park as a wildlife refuge will be irreversibly compromised.

iii. **Drivers of land use changes (Objective iii)**

Human population growth and agricultural expansion are the primary drivers of land use changes in Kitengela. Additional drivers include economic incentives from land sales, land tenure changes, urbanisation pressures, climate variability, and mining/quarrying activities. Land subdivision and privatization have fragmented open rangelands, introducing land uses incompatible with wildlife conservation, such as fencing and permanent developments, which further limit migratory movement.

iv. **Ecological impacts on wildlife (Objective iv)**

Land use changes have resulted in significant ecological impacts on migratory wild ungulates. Habitat fragmentation and loss have reduced the availability of continuous areas necessary for movement and survival. Behavioural changes, such as altered migration timing and avoidance of human-dominated areas, and increased mortality risks, particularly from roads and fencing, have further affected population stability. These combined effects threaten the ecological functionality of the Kitengela dispersal area. This means that wildlife populations are now experiencing both acute and chronic stress from landscape fragmentation.

6.2 Recommendations

6.2.1 Policy and Management Recommendations

Based on the foregoing conclusions, the following recommendations are proposed:

i. Strengthen land use planning and zoning in Kitengela to regulate urban, industrial, and agricultural expansion. The Kajiado County Government, in collaboration with local communities and conservation organisations, should also promote restoration of key habitats such as riverine vegetation and grasslands to support wildlife movement linked to Nairobi National Park.

ii. Human impacts on wildlife in Kitengela should be reduced by supporting community-based wildlife corridors linking rangelands to Nairobi National Park through partnerships between the Kenya Wildlife Service, Kajiado County Government, and local landowners, alongside community awareness programs to minimize habitat fragmentation and human–wildlife conflict.

iii. Land use drivers should be managed through the adoption of sustainable population growth and agricultural policies, revising land tenure systems to limit fragmentation, and regulating mining activities to minimize environmental degradation.

iv. Enhancing habitat connectivity and monitoring by focusing on habitat connectivity restoration, supporting ongoing research on migratory species, and strengthening partnerships among stakeholders for effective conservation.

6.2.2 Areas for Further Research

Further research should be conducted on:

i. Extent and effects of habitat fragmentation with a focus on impacts of development and quarrying activities in the Kitengela dispersal area and their implications for migratory wildlife species.

ii. High-resolution land use change analysis using high-resolution satellite imagery to investigate the linkages between land use changes, climate change, and their cumulative effects on ecosystem health and wildlife populations.

iii. Impacts of large-scale farming on wildlife, livestock, and the broader ecosystem within the Kitengela dispersal area to inform the design of integrated land use planning and conservation strategies.

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APPENDICES

Appendix A: Questionnaire for local residents

Questionnaire number.................. Date………/……. /2022

I am Samson Ouma, a Masters student at the University of Eldoret. I am conducting an academic study on the impacts of land use changes and developments on wild ungulates in Kitengela ecosystem. You have been randomly selected to participate in this study. Kindly spare a few minutes to answer all the questions listed. Your answers will remain confidential and used only for the purpose of this research.

SECTION A: PERSONAL DETAILS OF RESPONDENTS

1. What is your gender?

a. Male ( ) b. Female ( ) c. Other (specify) ………………………….

2. How old are you?

a.18 - 30 years ( ) b. 31-40 years ( ) c. 41-50 years ( ) d. 51-60 years ( ) e. over 60 years ( )

3. What education level did you obtain?

a. None ( ) b. Primary ( ) c. Secondary ( ) d. College ( ) e. University ( )

4. How many years have you lived in this area?

a. Below 5 years ( ) b. 5-10 years ( ) c. 10-20 years ( ) d. Over 20 years ( )

5. What is your current economic activity …………………………………………

SECTION B: DRIVERS OF LAND USE CHANGES IN KITENGELA ECOSYSTEM.

6. What is the size of your land?

a. Below 5 acres ( ) b. 5 -10 acres ( ) c. 10-20 acres ( ) d. 20-50 acres ( ) e. above 50 ( )

7. What type of land tenure do you practice?

a. Community ( ) b. Public ( ) c, Private ( )

8. How did you acquire your land?

a. Lease ( ) b. Inheritance ( ) c. Buying ( ) d. Given as gift ( ) e. Any other (Specify) ………………………………

ii. If by lease, for how long is the land under lease? …………. ………………

iii. If by inheritance, has it maintained its original size?

a. Yes ( ) b. No ( )

9. For what purpose do you use the land?

a. Residential ( ) b. Commercial ( ) c. Educational ( ) d. Agricultural ( ) e. Other(specify)…………………

10. i. Has the land changed users (ownership) since you acquired it?

a. Yes ( ) b. No ( )

ii. If yes, how many ………………………………

11. What factors have contributed to land use changes and developments in this area? (Use the table below and tick appropriately)

Cause of land use changes	**Tick**
Increase in human population	
Agricultural expansions	
Economic factors (Inflation)	
Changing land tenure policy	
Urbanization	
Fire	
Climate change (drought)	
Mining and quarrying	
Any other cause (specify)	

SECTION C: IMPACTS OF LAND USE CHANGES IN KITENGELA ECOSYSTEM

12. What are the negative impacts of land use changes and developments to the residents of this area? ……………………………………………………………………………

13. i. Do you benefit from the changing land use pattern in this area?

a. Yes ( ). b. No ( )

ii. If yes, list the benefits…………………………

14. What do you think are the impacts of land use changes and developments to wild ungulates in this area? (Use table below and tick appropriately)

Impact of land use changes	**Tick**
Habitat fragmentation	
Alteration of physical environment	
Road mortality	
Habitat loss	
Modification of animal behavior	
Increase human use of the area	
Mortality from the construction	
Any other (Specify)	

SECTION D: RELATIONSHIP BETWEEN INCREASE IN HUMAN POPULATION AND HUMAN WILDLIFE OCCURENCES

15. i. Have you ever experienced conflicts over land use with wildlife?

a. Yes ( ) b. No ( )

ii. If yes, how did you deal with it? ……………………………

16. i. Do you normally report case of human wildlife conflict you experience?

a. Yes ( ). b. No ( )

ii. If yes, to whom do you report the cases to……………………………

iii. If no, give reasons why you don't report the cases……………………

17. What is your view about HWC in this area?

a. Increasing ( ) b. Decreasing ( ) c. Constant/Not changed ( )

18. What is your opinion on the future of wildlife in this area …………………

19. What is your view on wildlife population in this area?

a. Decreasing ( ) b. Increasing ( ) c. Constant/Not changed ( )

20. i. Which wild animals used to be in this area but are now absent? ………………………

ii. Give any possible reasons that have led to their absence ……………………………

21. Which wildlife never used to be in this area in the past but are now present?

………..………

22. Do you have any other information that may be useful but is not covered in this questionnaire? …..…………………………………………………………………………

THANK YOU

Appendix B: Key Informant Interview guide questions

Good morning /afternoon. I am a Masters student from University of Eldoret, Department of Wildlife management. I am conducting research on changes in land uses that have occurred in Kitengela ecosystem, their causes and effects. I kindly request you to take some time and respond to the questions below. The information you give will be kept strictly anonymous and confidential. Thank you in advance for your cooperation.

Section A: Kenya Wildlife Service (KWS)

1. Who owns the land in Kitengela ecosystem?
2. How have land uses in Kitengela changed over the years?
3. What factors have contributed to the changes and what are the effects on wildlife?
4. What benefits do local residents derive from wildlife found in Nairobi National Park?
5. What problems does the KWS experience in an attempt to conserve wildlife in Kitengela ecosystem given that it is a non-park wildlife area?
6. Do you involve Kitengela residents in making decisions about wildlife conservation and management in Kitengela area?
7. What approaches is your organization employing to promote habitat conservation in Kitengela area and how effective are they?

Section B: National Environment Management Authority (NEMA)

1. Has any Environmental Impact Assessment study been done on any proposed new developments being put up in Kitengela area? Give examples of specific studies done if any and their results.
2. What are the potential effects of the mushrooming of slum developments next to Nairobi National Park on the wildlife therein?

Section C: Non-Governmental Organization involved in the conservation of wildlife resources

1. Which Kitengela wildlife migratory route conservation approaches is your organization involved in and how effectives are they in promoting conservation of habitat and wildlife?

Section D: Group Ranches and Local Community Based Organizations

2. Who owns the land in Kitengela area?
3. Have you observed or experienced any impacts of land use change in this ranch or Kitengela area in general?
4. What are the major causes of land use changes you have observed or experienced?

Appendix C: Research permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **856038**

Date of Issue: **31/October/2022**

RESEARCH LICENSE

This is to Certify that Mr.. Ouma SAMSON Samson of University of Eldoret, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kajiado on the topic: ASSESSMENT OF LAND USE CHANGES IN KITENGELA WILDLIFE DISPERSAL AREA AND THEIR IMPLICATIONS ON WILD UNGULATES IN NAIROBI NATIONAL PARK for the period ending : 31/October/2023.

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Appendix D: Similarity report

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Title	IMPACT OF LAND USE CHANGES ON MIGRATORY WILDEBEESTS AND ZEBRAS IN KITENGELA CONSERVATION AREA, KENYA
Paper/Submission ID	5629965
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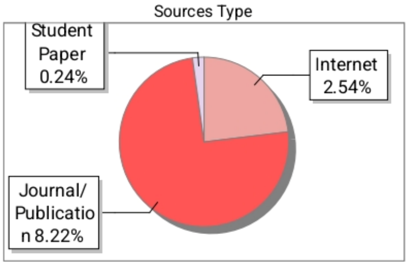

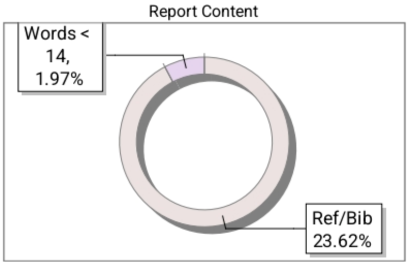

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