DYNAMICS OF AGRICULTURAL DEVELOPMENTS IMPACTING ON BIODIVERSITY CONSERVATION IN MERU NATIONAL PARK, KENYA

BY

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DECLARATION

This research project is my original work and has not been presented for a degree in any other university or for any other award.

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This research project has been submitted with my approval as the University Supervisor.

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DEDICATION

This work is dedicated to my husband Jonathan Munene, son Justin Munene, daughter Nyla Munene, family and friends.

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ABSTRACT

Meru National Park has witnessed a steady immigration of agricultural households from nearby high potential agro-ecological zones into its buffer zones. The situation has subjected natural habitats that formerly served as communal grazing lands and wildlife dispersal areas to fragmentation and alteration. To date, the most affected zones are wetlands of the western and southern buffer zones. These zones are most critical for livestock and wildlife, particularly as dry season grazing areas. The main objective of this study was to determine the impacts of agricultural development on biodiversity conservation in Meru National Park. The specific objectives were to document land fragmentation and subdivision trends and changing crop types, to determine the impacts of land use changes on the approach used for community-based conservation and to determine the size and extent of human-wildlife conflicts. The study applied qualitative, quantitative, descriptive and exploratory research approaches. Primary data was obtained from household questionnaires, key informant interviews, high resolution google earth images and Geographic Information System imagery of the study area. Secondary data was obtained from published and un-published reports. Both qualitative and quantitative techniques were used to analyse the collected data. The quantitative techniques were done through coding the data from questionnaires. This was followed by analysis using the Statistical Package for Social Science. A substantial part of the analysis was based on descriptive statistics such as frequencies and cross-tabulation. Spatial analysis was used to explore the land use and land cover changes of the study area using four time-period data sets (2000, 2005, 2010 and 2016). Photographs were used to document the current situation on the ground. Spatial analysis indicates that the area under rain-fed shrub vegetation reduced significantly by 66.69 km^2 between 2000 and 2016. This is majorly attributed to clearing of shrub vegetation to covert these areas into farmland. 76% of farmers in the study area are using irrigation to increase their farm outputs and to farm all year round. The water used for irrigation is abstracted from rivers and streams that drain from the base of the Nyambene Hills and flows into the park. This increased irrigation has resulted in lower water volumes and in some cases leading to no water flowing into the park. Between 2014 to 2016, The total annual number of human-wildlife conflict incidences in 2014, 2015 and 2016 increased from 367, 526, and 540 respectively. These conflicts affected maize and bananas farmers the most with baboons, elephants, buffaloes and monkeys being involved in the conflicts frequently. Whereas traditional land sizes were 20-35 ha in 1990s, the current farm sizes are medium scale ranging between 1 ha and 5 ha, an indication of the rapid land fragmentation in the study area. Meru National Park has increasingly witnessed complex interactions between conservation and socio-economic needs and pursuits of households occupying its buffer zones. This study therefore recommends implementation of sustainable biodiversity conservation strategies that do not hinder socio-economic development. This should be implemented by Kenya Wildlife Service in collaboration with community-based groups and key stakeholders.

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ACRONYMS

CBC	Community Based Conservation
CIDP	County Integrated Development Plan
GDP	Gross Domestic Product
GIS	Geographic Information System
IUCN	International Union for Conservation of Nature
KFS	Kenya Forestry Service
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
MAM	March April May
MCA	Meru Conservation Area
MENR&RDA	Ministry of Environment, Natural Resources and Regional Development Authority
MDGs	Millennium Development Goals
MNP	Meru National Park
NEMA	National Environment Management Authority
PES	Payment for Ecosystem Services
RCMRD	Regional Centre for Mapping of Resources for Development
SOND	September October November December
SPSS	Statistical Package for Social Sciences
WRMA	Water Resources Management Authority

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

According to Joppa (2012), biodiversity degradation is occurring at an alarming rate globally. This continues to happen even with an increase in establishment of protected areas whose primary goal is to slow the decline in global biodiversity. Jenkins *et al.,* (2009) also note that over the past 100 years, there has been growth of protected areas globally which is estimated to cover more than 12% of the terrestrial environment

Wheeler & Beatley (2004) argue that there are conflicts between biodiversity conservation and urban development. In most cases, biodiversity conservation will often conflict with demands for housing and economic development. For instance, the government of Kenya has planned to develop a road bypass through Nairobi National Park (NNP) with a 200m incision into the park. These plans are going on despite the strong opposition by NNP because of the eminent danger this poses to wildlife conservation in the park (KWS, 2015).

Hardoy *et al*. (2001) also agree with this view and they illustrate the large gap between stakeholders whose primary concern is biodiversity conservation and those whose primary concern is development needs. This implies that to deal with issues on protected areas, bridging interests of conservation and development should be one of the main approaches (Mitlin and Satterthwaite, 2001).

Southgate & Hulme (1996) noted that Kenya's policies on land use are aimed at promoting sustainable development although their restriction to few sectors of the economy has resulted in anti-conservation implications for the biodiversity conservation sector. For instance, the government of Kenya has sought to address rapid increase in population and attainment of self-sufficiency in food production through increasing agricultural production in the ASALs through conservation agriculture and rangeland management. This policy has provided agricultural communities occupying high potential agro-ecological zones with a perfect opportunity to seek

alternative land for settlement and crop cultivation in Kenya's rangelands. This has resulted in the migration and settlement of farmers in the park's buffer zone.

According to Kirori (2015), Kenya's policy on rural development promotes the improvement and sustenance of the livelihoods of rural households in marginal areas without much consideration for biodiversity conservation. This situation has led to an increase agricultural development in areas surrounding Meru National park majorly comprising of agriculture mixed with livestock rearing and small artisanal businesses. On the national scale, agriculture is a key enterprise engaging more than 75 per cent of Kenya's total population.

With a few regional exceptions, human populations around protected areas and subsequent agricultural activity around protected areas have grown exponentially. This has produced greater anthropogenic pressure on protected areas. Human-protected area interactions are a determinant of how effectively protected areas can conserve biodiversity. This interaction is also a potential determinant that shapes patterns of agricultural development (Joppa, 2012).

According to Otuoma (2005), the above situation has been exacerbated by the ever-increasing human population growth rate in Meru Conservation area (MCA). He notes that an 83% increase in human population has been recorded in the MCA's western, southern and northern buffer zones. This figure closely relates to the 86% increase in human population reported in the 1999 household census by the Central Bureau of Statistics in the six districts bordering the MCA, which indicated that human population increased from 1.56 million in 1979 to 2.90 million in 1999 (Ibid). This coupled with other dynamics that come about as a result of agricultural development in MCA have exerted immense pressure on biodiversity conservation in MNP.

Some flora and fauna find it very difficult, or impossible, to survive in areas where their habitat has been disturbed or changed. This disturbance or alteration of the natural habitat is usually caused by anthropogenic activities surrounding a national park (Richard Dolesh *et al,* 2009).

1.2 Problem Statement

Meru National Park (MNP) has witnessed a steady immigration of agricultural households from nearby high potential agro-ecological zones into its buffer zones which are gazetted as free hold land and not as a reserve. This has brought about land ownership related conflicts that have negatively impacted on biodiversity conservation. This situation has subjected natural habitats that formerly served as communal grazing lands and wildlife dispersal areas to fragmentation and alteration. This has been brought about by migrant households that have taken up land in the park's buffer zones for settlement and crop cultivation (KWS, 1994).

To date, the most affected zones are wetlands of the western and southern buffer zones. These zones are most critical for livestock and wildlife, particularly as dry season grazing areas. MNP has therefore increasingly witnessed complex interactions between conservation and socio-economic needs and pursuits of households occupying its buffer zones. Land use and land cover changes are indicators of these complex interactions (KWS, 2006).

Disputes have risen from conflicts of interest among agriculturalists, pastoralists and conservationists with wildlife as the common ground of contention, particularly on the western, southern and northern boundaries of the park. The reported number of HWC incidences associated with agricultural activity in the study area has been increasing. The statistics for 2014, 2015 and 2016 are 367, 526, and 540 respectively. Agriculturalists are using irrigation to increase their farm outputs and to be able to farm all year round. The water used for irrigation is abstracted from rivers and streams that drain from the base of the Nyambene Hills and flows into the park. This increased irrigation has resulted in lower water volumes and in some cases no water flowing into the park (Otuoma, 2005).

After recognition of the possible dangers of wildlife interaction with settlers in the park's buffer zone, KWS erected an electric fence to cover the western, southern and northern boundaries of the park. Nonetheless, human wildlife conflict continues to rise during drier periods as wildlife move beyond the electric fence in search of green fodder thus destroying crops in the farms which are located in the wetlands of the study area (KWS, 1994).

The electric fence limits wildlife movement into dispersal areas for the different seasons. This changing land use has posed serious challenges for implementation of community-based conservation. These areas are experiencing the expansion of small-holder cultivation in wildlife dispersal areas. This situation has been reported to reduce animal home range in MNP's dispersal areas, leading to increased human-wildlife interaction, which has degenerated into human-wildlife conflicts (KWS, 1994; Little, 1994; Said *et al.*, 1997).

This study therefore seeks to determine the effects of agricultural development on biodiversity conservation in MNP. This was assessed from the resultant human-wildlife interactions, impacts of socio-economic activities around MNP, human population dynamics in areas surrounding MNP and existing biodiversity conservation measures being implemented by KWS. The research also explored possibilities for biodiversity conservation and management alternatives that recognise both human agricultural needs and conservation needs in order to maintain ecological function of the protected areas.

1.3 Research Question

This study was guided by the following research questions;

1. How has habitat change and land fragmentation in MNP's buffer zones impacted on biodiversity conservation?
2. How have land use changes impacted on the approach used for community-based conservation?
3. What is the size and extent of human wildlife conflicts in MNP's buffer zones?

1.4 Research Objectives

The main objective of this study was to determine the impacts of agricultural development on biodiversity conservation in Meru National Park (MNP) buffer zone area.

1.4.1 Specific Objectives

The specific objectives for this study were;

1. To document land fragmentation and subdivision trends and changing crop types in MNP's buffer zones;
2. To determine the impacts of land use changes on community-based conservation; and
3. To determine the size and extent of human-wildlife conflicts in MNP's buffer zones.

1.5 Justification and Significance of the Study

An integrated strategy of biodiversity management and conservation is essential in ensuring continued survival of the biodiversity in MNP and to ultimately allow the park to function normally as intended. The findings of this study will form an integral part in contributing towards the efforts being made for sustainable biodiversity management and conservation in MNP.

Findings of this study will be used to mainstream sustainable biodiversity management and conservation into existing policies, strategies and management frameworks for MNP. Specifically, this study compliments efforts by KWS in implementation of their Meru Conservation Area Management Plan (2007-2017) whose main goal is to support and guide the coordinated and integrated management of the four constituent PAs that make up the MCA including MNP. Ultimately, this study contributes towards realisation of Kenya's Vision 2030 which provides for protection of genetic resources and biological diversity as specified in Article 69 (e).

1.6 Theoretical Framework

This section reviews the theory that highlights biodiversity conservation challenges that are brought about by agricultural development. The concept of environmental education and livelihood and survival requirements of a community has been integrated into the system to support the effect of sustainable agricultural production in areas adjacent to conservation areas.

1.6.1 Planned Behaviour Theory

This theory was developed by Icek Ajzen in (1985). He discusses that the contributing factor of any individual's behaviour is the individual's intent to undertake or to not undertake that behaviour which is normally influenced by personal norms, attitudes and perceived behavioural control. He further argues that all these attributes are in turn affected by a set of beliefs.

In context of the challenges of biodiversity conservation in Meru National Park, personal beliefs could affect people's attitude towards the park which influences resource use in the park. Subjective norms constitute perceptions and social pressures to undertake or not to undertake a certain action. For the case of MNP, the adjacent community may affect use of park resources based on whether that action is approved or disapproved by the community.

Perceived behavioural control is determined by a person's ability, skills, tools and experience that is required for successful implementation of an action that affects resource use like in the case of Meru National Park. Kaplan (2000) further argues that people make decisions based on knowledge that they have about the subject. The knowledge they possess may promote pro-conservation or anti-conservation behaviour towards natural resources in conservation areas.

Other external factors that could affect conservation practices of people were considered, these are environmental education and livelihood and survival requirements. This theory has been illustrated in figure 1;

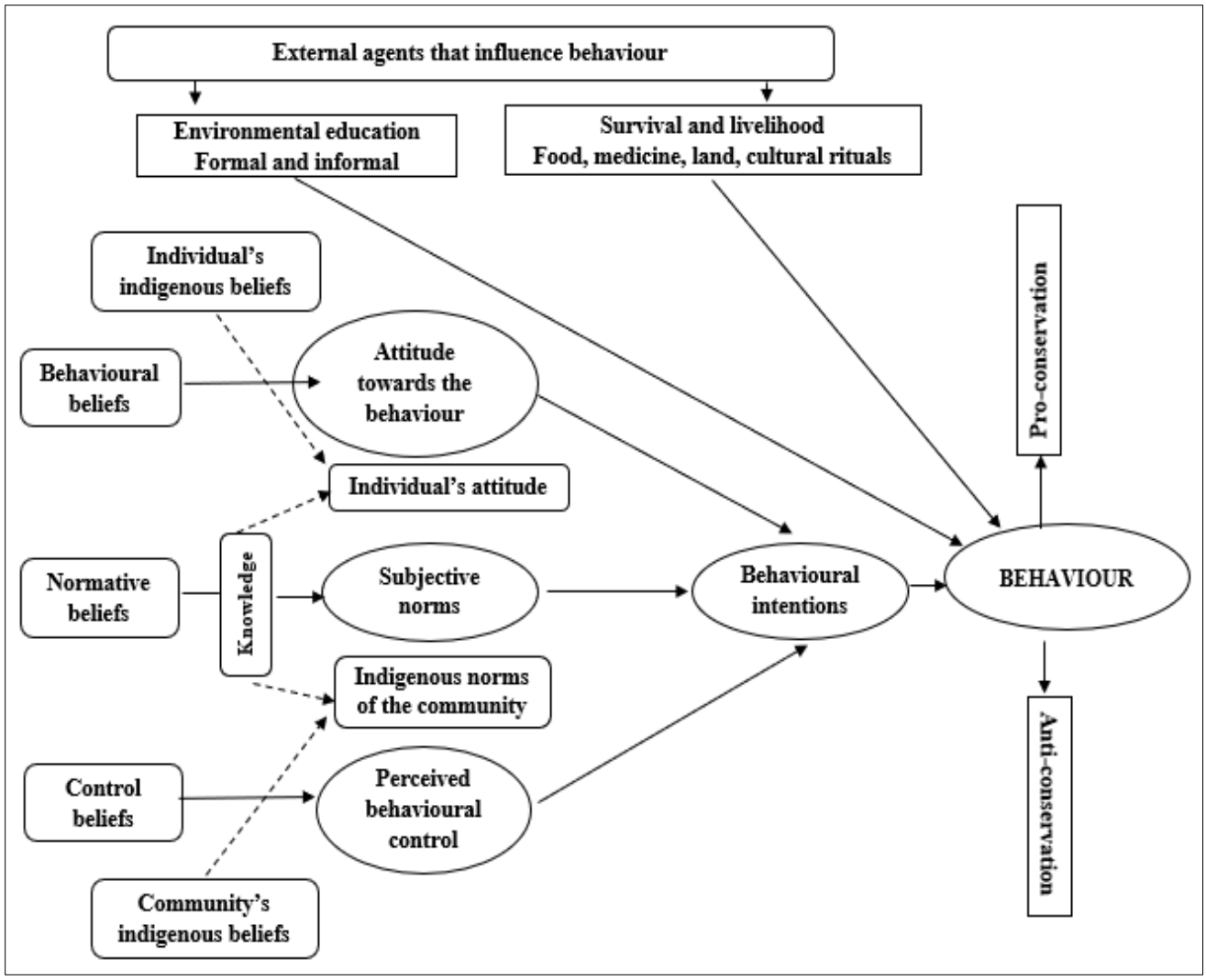


Figure 1 Planned behaviour theory

1.6.2 Maslow's Hierarchy of Needs Theory

Maslow's hierarchy of needs theory (1943) states that people are driven to achieve certain needs with some needs taking priority over others. Maslow explains that the most fundamental need is physical survival which subsequently will be the first thing that motivates human behaviour. This relationship builds up the pyramid as different needs are met.

Maslow's hierarchy of needs theory identifies six levels of needs in descending order namely; physiology, safety, love and belonging, esteem, self-actualisation, and self-transcendence (Maslow, 1954). Figure 2 gives an illustration of this theory;

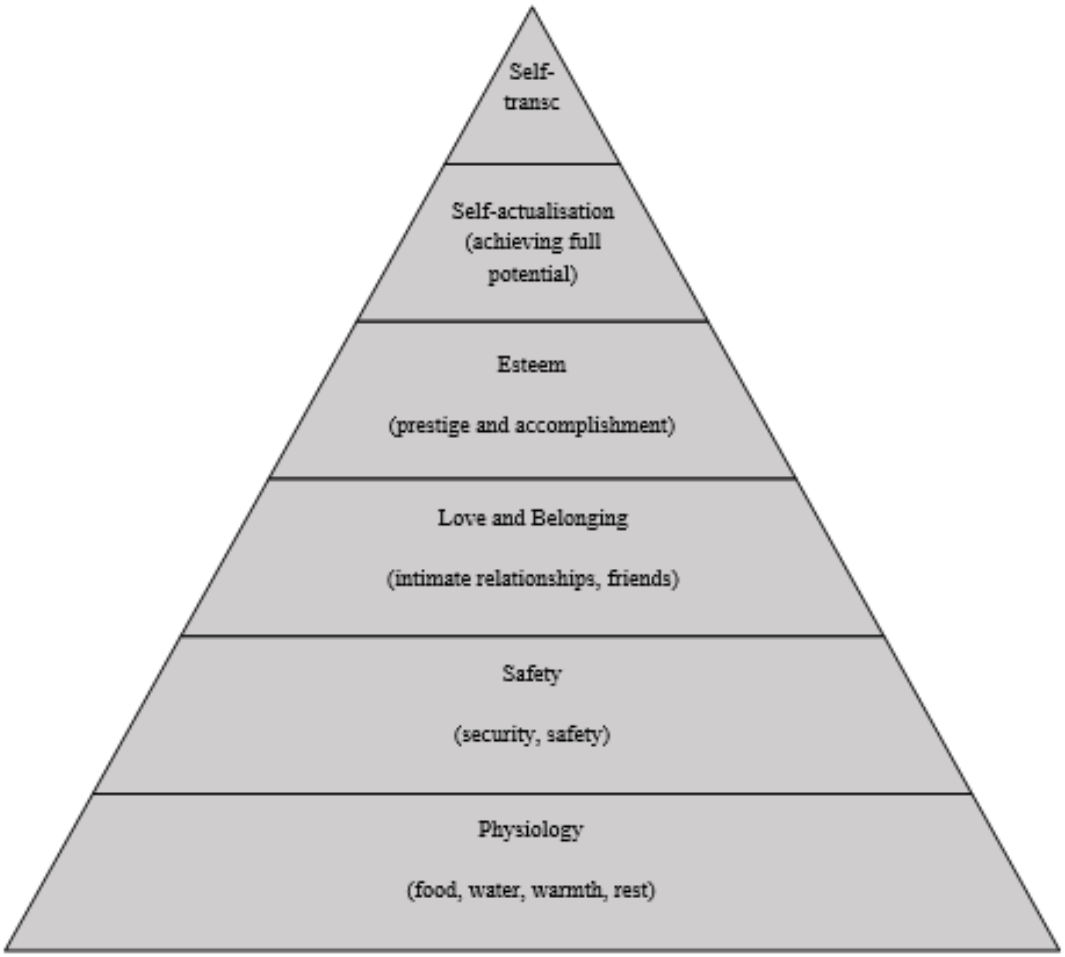


Figure 2: Maslow's hierarchy of needs theory

Maslow's theory on the ranked arrangement of human needs is useful in explaining the dynamics that occur with regard to rural development and biodiversity conservation. According to Maslow, the physiological needs have to be realized before one can move to the next level. Notably, the high-level needs in Maslow's hierarchy are closely related to cultural practices, values, and people's beliefs which has a major role to play in the case of Meru National Park (Maslow, 1954).

More often than not, decision makers have to make a decision between encouraging economic growth while ensuring protection of natural resources, but this has been an arduous task as getting a balance between the two fundamental elements has proved to be challenging. This theory plays an important role by explaining how human beings make decisions that influence biodiversity conservation.

1.6.3 The General Systems Theory

This theory was developed by Bertalanfy (1951), who argues that the ecosystem consists of mutually related subsystems, where the destruction of one of the sub-system leads to the modification of the entire system. He further argues that the natural environment is the sum total of all the external factors that influence the livelihood of an organism, here the physical environment which comprises natural resources such as biodiversity is considered.

Consequently, the strive for economic growth which is agricultural development in this case, natural and social environments are subjected to pressure that affects the entire system. Bertalanfy further emphasized that real systems are open to interactions with their environments and that they can acquire qualitatively new characteristics through development resulting in continual evolution over time (Bertalanfy, 1968).

The general systems theory conceptualizes biodiversity degradation and adverse social and economic effects as the response of unsustainable agricultural practices which negatively impacts the environment. Biodiversity degradation and negative social and economic challenges such as species loss and extinction, migration, human-wildlife conflict, changes in landscape and resource depletion is seen as the reaction to unsustainable agricultural practices to biodiversity conservation (Bertalanfy, 1951).

This theory illustrates that destruction of one of the sub-system leads to the modification of the entire system and that human beings has the potential to negatively or positively affect the environment based on how they respond to changes in the environment. Consequently, the environment also responds to the changing conditions set forth by human manipulation which leads to a dynamic equilibrium that continues to adjust and readjust in space with time (Olofin, 1989).

1.7 Conceptual Framework

This conceptual framework was developed in response to the fact that protected areas are continually facing challenges of delivering their main role of biodiversity protection while also

responding to societal needs in the wake of continued agricultural development. Protected areas provide important services, such as freshwater availability; water harvesting; water purification; erosion control; habitat for species; climate regulation; protection from environmental hazards, such as floods or storms; and many other services, such as nature tourism and spiritual and intrinsic values (Greenhalgh, Selman, and Guiling 2006).

The ecosystem service management approach helps us acknowledge that humans depend on and benefit from protected areas and, therefore, reveals the social benefits that are obtained from ecosystem services, which can be used to enhance current conservation efforts. This provides the stimulus for conserving nature, which requires policies and appropriate management strategies. This has particularly led to the present situation of protected areas in ecological networks for the conservation of species and habitats (Ray *et al*., 2014).

However, there may also be services whose provision will be antagonistic to biodiversity conservation interests or to other services. If left to run in isolation, or unsustainably, this loop may have severe detrimental effects on biodiversity that is not required to provide non-cultural services. Thus, it is of utmost importance that *both* loops of the framework are maintained and equally important, that the loops not be considered in isolation of each other but must be closely linked in all appropriate places and at all scales of organisation (Rounsevell *et al.,* 2010).

All this implies an acute awareness of the dynamic nature of ecosystems and our societal interactions with them – change to any part of the system, biological or socio-economic, from within or external, is likely to have profound consequences for the other components and their relationships. This re-emphasises that it would be naïve to continue to consider biodiversity conservation as something on its own; and that entire Socio-Ecological Systems (SES) are the appropriate level for responding to future conservation needs (Greenhalgh, Selman, and Guiling 2006).

The increasing population and intensification of agricultural activities outside the park is exerting a lot of pressure on the park and threatening sustainable biodiversity conservation. In order to govern complex ecosystems like these, there is need to incorporate all relevant stakeholders. To

achieve this, adaptive co-management strategies need to be employed because community-based conservation and participatory approaches have been reported to reduce social conflict and increase the effectiveness of conservation efforts (Otuoma, 2005).

The ecosystem service management concept provides a common language that allows all stakeholders' engagement in a participatory decision-making process regarding protection of protected areas and the biodiversity in the protected areas (Mace, 2012). The ecosystem management concept has been integrated with the 'sustainable development' model that implies a cohesive approach to managing different and often competing needs against an awareness of the environmental, social and economic limitations that society faces. Integration is one of the 'first order principles to implement and institutionalise sustainable development (along with system integrity, intergenerational equity, livelihood sufficiency opportunity, precaution, adaptation, and long-term planning)'.

Figure 3 gives a snapshot of an integrated strategy of biodiversity management and conservation which focuses on; (a) integration of conservation strategies and policy with other sectors – agriculture, transport, industry, etc. (b) inclusion of the sustainable provision of ecosystem services within the bounds of management for conservation would be one way to add value to present conservation management strategies and (c) knowledge on balancing the conflicts between economic service provision and biodiversity conservation of protected areas

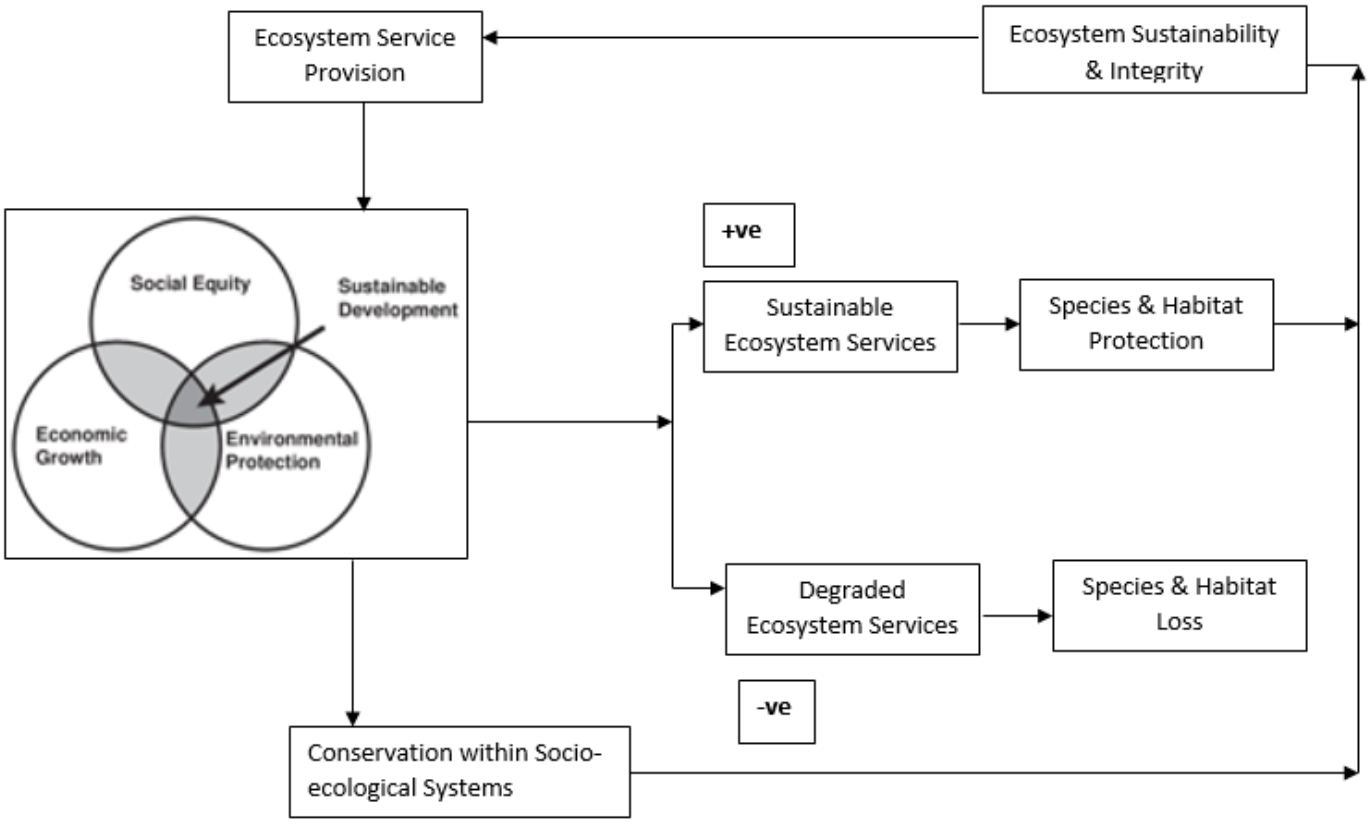


Figure 3: Conceptual framework for biodiversity management and conservation
Source: Author 2017

1.8 Scope of the Study

This study covered the buffer zone adjacent to Meru National Park which are characterized by heavy agricultural activity. The target population was the community residing in these buffer zones which includes farmers, KWS and other relevant stakeholder such as government institutions and other key private sector players. The study maps the extent to which agricultural development in MNP's buffer zones has impacted on biodiversity conservation in MNP; documents land fragmentation and subdivision trends and changing crop types in MNP's buffer zones; determines the impacts of land use changes on the approach used for community-based conservation; and determines the size and extent of human-wildlife conflicts in MNP's buffer zones. All these components contribute to the realisation of an integrated strategy for biodiversity management and conservation for MNP.

CHAPTER TWO
LITERATURE REVIEW

2.1 Agricultural development around protected areas

Globally, there is evidence of an increase in migration and population growth near protected areas. According to Wittmeyer *et al*. (2008), there has been an increase in population growth within a 10km buffer zone of protected areas as compared to similar rural areas without parks. Terborgh and Peres (2002) also adds to this discussion by noting that certain segments of the conservation community are concerned that protected areas may create a sort of "conservation catch-22" situation by encouraging human in-migration near their borders and thereby accelerating their isolation from natural landscapes.

Terborgh and Peres (2002) suggest that this pattern reflects in-migration due to people's perception of the economic, social and infrastructural benefits of parks. Further, they suggest that this pattern shows that conservation does benefit local communities and they further argue that this increasing population growth trend could pose a threat to biodiversity conservation in and around protected areas.

West *et al*. (2006) noted that in some regions protected areas may be affected by traditional modes of agricultural development with local communities shifting to agricultural development activities as opposed to biodiversity conservation activities. This agricultural development utilises the available natural resources in and around protected areas such as rivers and swamps for subsistence farming, a situation that threatens the availability of water (for what?) to biodiversity in and outside of the protected areas.

According to DeFries *et al.* (2007), as land use change occurs outside the administrative boundaries of existing protected areas, with potential negative consequences for the ecological functioning of the protected areas themselves, the trade-offs between human uses and longer-term conservation of ecosystem services become complex. The challenge here is to enforce ecological principles to find opportunities that do not impractically constrict human land use, while promoting pro-conservation approaches in protected areas.

This research paper looked into the possibilities for management alternatives for protected areas that recognize both conservation needs to maintain ecological function and human needs that are obtained from areas outside the park boundaries "unprotected areas". According to Vin *et al*. (2007), appropriate biodiversity management and conservation systems, if applied well with relevant stakeholder consultation, can lead to the achievement of "win-win" situations that satisfy human needs while maintaining ecological functioning of protected areas. This has mostly been achieved where conservation results in direct economic benefits as in tourism and Payment for Ecosystem Services (PES).

Examples of such "win-win" scenarios include a case study of the Wolong Nature Reserve that is situated in Sichuan, China (Vin˜a *et al*. 2007) where a ''win–win'' scenario was attained through provision of non-agricultural employment opportunities for local community which successfully reduced the pressure on the giant panda (*Ailuropoda Melanoleuca*) habitat from tree logging for fuelwood and agriculture expansion into this area. This approach also enhanced the livelihoods of the local community.

Another case study is in Kenya, Kitengela where the payments for ecosystem services approach was used to deter the local community from erecting temporary and permanent fences on their land which would ultimately restrict the wildebeest migration through this corridor. This approach enabled the community to increase their sources of income during dry spells Kristjanson et *al* (2002). The ability of this approach to be effectively implemented relies on the existence and implementation of ecological conservation strategies with a clear understanding of the potential for habitat loss from human pressures and the implications these actions have on wildlife populations.

2.1.1 Agricultural development in Kenya

The agriculture sector is a pivotal development pillar for Kenya's economy and is the major source of livelihood for majority of the rural population. The agriculture sector contributes about 26% of Kenya's GDP and provides employment for about 75% of the total population (RoK, 2015). Of

the total export produce, agriculture accounts for two thirds of the export produce thereby providing a significant source of revenue for the country.

In accordance with the Constitution of Kenya 2010, the agriculture function has been devolved to the County level to encourage a paradigm shift in development planning. The national government and its devolved function are expected to work closely to ensure national coherence of policies in Kenya and thus contributing towards the attainment of Kenya's Vision 2030 that aspires to make Kenya a globally competitive and prosperous nation with a high quality of life for all citizens by the year 2030 (RoK. 2010)

Rural agricultural development in the study area has undergone some significant changes as compared to traditional farming practices in Kenya which majorly focussed on food and cash crop production combined with livestock keeping. In the recent past, most farmers have shifted to horticultural production due to the higher revenues of produce obtained at various markets (RoK, 2013).

In Meru County, tea, coffee, bananas and khat (miraa) farming are the dominant cash crops in the Nyambene ranges and this has phased out food crop production in the area. The current average farm size ranges from 1.8ha for small scale farmers to 18.25ha for large scale farmers (RoK, 2013). Land subdivision has significantly reduced the average acreage to 1.8ha. The main livestock kept are goat, cattle, sheep, pig, rabbits and poultry reared in small scale because majority of the land has been set aside for farming of food and cash crops (Ibid).

2.2 Environmental and socio-economic impacts of agricultural development on biodiversity conservation in protected areas

According to Brandon and Gorenflo (2006), in borderline lands undergoing rapid transitions from wild lands to stable human land uses, extraction of resources takes the form of rapid agricultural expansion, logging, mining, and hunting. Extraction and over-exploitation of such natural resources has posed serious biodiversity conservation challenges in these boundary landscapes because of a lack of institutional infrastructure and inadequate enforcement (Brandon and Gorenflo

(2006). The most immediate action needed is identification and protection of critical wildlife habitats and corridors before they are converted into stable human land uses.

Norton-Griffiths (1997) and Ottichillo, (2000) report that rural agricultural development has resulted in various challenges such as habitat fragmentation, competition for water resources, blocking of wildlife dispersal areas and migratory routes, human wildlife conflicts and negative perception towards conservation.

Similarly, there are ecosystems in Kenya that have experienced human influx for purposes of agricultural farming such as the Mau escarpment, Mt. Kenya National Park, Aberdare National Park, and Mt. Elgon among others. Kenya Wildlife Service and the Forest Department are now dealing with a new challenge of regulating and containing encroachment to minimize habitat loss and degradation that may eventually lead to biodiversity destruction (Ottichillo, 2000).

Listed below are some of the challenges that are being faced by protected areas and conservationists as a result of the ever-increasing activities that are associated with agricultural development around protected areas.

2.2.1 Loss of biodiversity

Biodiversity loss in this context is defined as the variety of all life forms including animals & plants lost in their natural environment as a result of agricultural activities. Sindiga (1995) and Mwale (2000) argue that human encroachment on identified critical biodiversity depository sites to acquire agricultural land has been happening since the 1970's and 1980's which has led to the transformation of critical biodiversity depository sites into low potential rangelands which coincidentally are the prime wildlife ecosystems.

According to Mwale (2000), increased human population outside park boundaries and in the buffer zones of protected areas has resulted in increased demand for land as well as increased pressure and threats to wildlife and other biodiversity species in Kenya. Kameri (2002) also notes that high potential areas in western and Central Kenya as well as some parts of the Rift valley where agriculture is the predominant land-use have observed a reduction and in some cases extinction of

many biodiversity types, other effects include substantial alteration and loss of wildlife habitats. Agricultural development has led to the conversion of natural habitats to crop and pasture land. These scattered land conversion patterns have led to fragmentation of existing forests and reduced numbers and abundance of species that can be supported by unconverted land (Lewiset *et al*, 2009, Laurance *et al*, 2011).

2.2.2 Human wildlife conflicts

As human populations expand and natural habitats shrink, people and animals are increasingly coming into conflict over space and natural resources. KWS (1994) defines human-wildlife conflicts as any or all disagreements that relate to destruction of property, loss of life, loss of property and interference of human rights or groups brought about directly or indirectly by wild animals. The wild animals, many of which are already threatened or endangered, are often killed in retaliation or to 'prevent' future conflicts.

Until recent times, the basic premise of human-wildlife conflict has been as a result of a myriad of challenges including; (a) changes in land use especially rural agricultural development and sedentarization of pastoralists in rangelands, (b) inadequate wildlife control (c) ban on hunting and capture of wildlife and wild life products (d) natural increase in wild animal numbers (e) conflicting wildlife conservation policies and laws outside protected areas (f) management challenges of wild life custodians e.g. poor law enforcement, inadequate community mobilisation for reinforcing wildlife conservation, poor animal control inside and outside protected areas and unsatisfactory revenue sharing schemes accrued from biodiversity conservation activities (KWS, 2007).

Socio-economic issues can also cause and exacerbate human-wildlife conflicts. An increase in human population around protected areas normally leads to an increase in demand for natural resources particularly among livestock keepers and wildlife. Such situations have resulted in increased wildlife-human interactions that have degenerated into human-wildlife conflicts (KWS, 1994).

2.2.3 Over-exploitation of natural resources

According to Agwata (2006), the volume of water in rivers, streams and springs entering Meru National Park from the Nyambene hills has already been reduced which can be attributed to the increasing permanent agriculture in these areas. Other contributing factors include the ever-increasing human population in the park due to illegal excisions of the forest and encroachment due to human settlements. More specifically, KWS (2007) notes that the MNP management has already identified that river systems are facing various threats which include abstraction of water for irrigation, swamp drainage, conversion of riparian habitat, destruction of catchment forest, planting inappropriate exotics, use of agricultural chemicals and sand scooping for construction.

Terborgh and Van Schaik (2002), acknowledge that in more stable, non-boundary landscapes, challenges and management opportunities vary and are pegged on the socioeconomic setting. Locations that have human populations are heavily reliant on local resources, the most immediate management challenge is promotion of livelihood alternatives that are deemed to improve human well-being and result in reduced over-exploitation of forest products and other land resources such as rivers and swamps.

Terborgh and van Schaik (2002), further note that this is perhaps the greatest conservation challenge for the coming decades. In developed countries, management that deflects development away from critical habitats might be achieved through collaboration with existing institutions for zoning and promotion of alternative economic incentives.

2.2.4 Habitat fragmentation

According to Wilcox and Murphy (1985), habitat fragmentation is one of the greatest primary threats to species extinction which poses serious challenges to biodiversity conservation. They further argue that variations in an organism's preferred habitat may result in population fragmentation and ecosystem decay. Geological processes may result in habitat fragmentation that slowly alters the layout of the physical environment or can be caused by human activity such as land conversion for agricultural use which alters the physical environment more rapidly. Severe habitat fragmentation can result in species extinction in some cases.

Over long-time frames - at least thousands of years, landscapes are fragmented by geological forces (e.g., continental drift) and climate change (e.g., glaciations, changes in rainfall, sea level rise). Over short periods (decades or months), natural disturbances, such as forest fires, volcanoes, floods, landslides, tornadoes, hurricanes, earthquakes and windstorms modify and fragment landscapes. Additionally, landscapes are naturally fragmented by mountain ridges, canyons, rivers, and lakes. Some ecosystems commonly occur in remote areas and are thus naturally fragmented. These natural processes create the habitat heterogeneity and landscape diversity upon which many species depend (Lewis *et al* 2009, Laurance *et al* 2011).

Increasingly, conservation professionals are faced with managing fragmented landscapes. This challenge is complicated by the diverse responses of species to fragmentation and the complex decisions surrounding conservation of land. As with any conservation or forest management plan, when examining a fragmented landscape, it is essential to identify clear goals (Wilcox and Murphy, 1985).

2.2.5 Socio-economic benefits of biodiversity conservation

Naidoo and Ricketts (2006) state that there are various socio-economic benefits of biodiversity conservation in various sectors including agriculture which would be impossible without essential ecosystem services which enable the breakdown and recycling of nutrients within the soil. A huge variety of immeasurable creatures perform this service.

Biodiversity is also important for pollination of plants on which a wide range of crops, including forage plants, depend. It is also vital to pest control. Similarly, commercial forestry relies on biodiversity for nutrient recycling and pest control. Some forests are important for hunting or as a reservoir for wild food (e.g. fungi). In addition, many forests, natural or commercial, are important for human utility, as amenities for recreation and habitats for wildlife (Kiringe & Okello, 2007)

Biodiversity also performs an important service for recycling nutrients and ensuring desirable water quality for agricultural use, fisheries and human consumption (Vin˜a *et al*., (2007).

A very important contribution is made by biodiversity to human welfare which occurs directly through appreciation of nature i.e. nature watching, eco-tourism, water sports etc. A functioning ecosystem contributes to the supply of nutritious food and quality water that are essential to human health. (DeFries *et al*., 2007).

2.3 Legal and policy framework governing biodiversity conservation in Kenya

The legal and policy framework governing biodiversity is important as it forms the basis for all conservation activities in the country. Kenyan policy recognises the land surrounding MNP as communal land which has led to the migration and settlement of farmers in the study area. This has resulted in the degeneration of wildlife-human interaction to HWC and poaching of wildlife. Other policy implications include the promotion of agricultural activity for community sustenance in marginal areas which includes the belt around MNP. The following policies govern biodiversity conservation in Kenya;

2.3.1 The Constitution of Kenya (2010)

Chapter 5 of the Constitution of Kenya is dedicated to environment and land hence reflects priority accorded to these sectors by the national government. Chapter 5, Part 2, Section 69 (1) mandates the State to ensure sustainable natural resource management and share equitably benefits accrued from natural resources. In addition, the State is required to conserve and protect biodiversity and indigenous knowledge, encourage public participation in natural resource management, set up environmental management tools such EIAs and EAs, eliminate processes and activities that are likely to endanger the environment and subsequent resources such as wildlife (RoK, 2010).

Further to the above, Chapter 5, Part 2, Section 69 (2) requires every individual to take responsibility of promoting environmental integrity, as well as adhere to regulations governing the environment and land. In the Fourth Schedule (Distribution of functions between the National government and County governments), the National government is mandated to protect, conserve and sustainably manage fishing, hunting, gathering and protection of animals and wildlife (RoK, 2010).

2.3.2 Kenya Vision 2030

Kenya's Vision 2030 is anchored on three pillars (Economic, Social and Political) of which the environment is incorporated in the Social Pillar. This Pillar seeks to build a just and cohesive society with social equity in a clean and healthy environment (RoK, 2008).

Transformation of the environmental sector is being undertaken through promotion of environmental conservation; adoption of economic incentives to improve pollution and waste management. Additionally, efforts are being put towards fostering public private partnerships for improved water, health and sanitation delivery. Enhancement of disaster preparedness in disaster prone regions and ensuring good environmental governance and planning through promoting policy coherence is also being implemented. (RoK, 2008).

Further to the above, this development Plan acknowledges the need to achieve the Millennium Development Goals (MDGs) which expire end 2015. Notably, achieving environmental sustainability is amongst the MDGs (RoK, 2008).

2.3.3 Environment Management and Coordination Act (EMCA), 1999

EMCA, 1999 is Kenya's governing law on environment and conservation. The following institutions have been established under this Act: National Environment Management Authority, Public Complaints Committee, National Environment Tribunal, National Environment Action Plan Committees, and County Environment Committees. NEMA is the "instrument of government charged with the implementation of all policies relating to the environment and exercises general supervision and coordination over all matters relating to the environment" (RoK, 2015).

2.3.4 Kenya Wildlife Strategic Plan (2012/2017)

The KWS Strategic Plan (2012/2017) is founded on the following themes: conservation stewardship, people excellence and collaborative partnership**.** As noted above, a couple of institutions contribute to the management of natural resources (including wild life), however, KWS remains the lead body managing parks and reserves in Kenya (KWS, 2015).

As indicated in the KWS Strategic Plan (2012 – 2017), KWS faces a series of institutional challenges such as financial constraints, inadequate human resources, incomplete biodiversity inventory, inadequate risk management strategy, limited knowledge and minimal implementation of available information (RoK, 2013). These factors impede realization of the KWS's Vision. It is important to note that the bottlenecks also affect performance of KWS at the Park and reserve level (KWS, 2015).

2.3.5 The National Wildlife Conservation and Management Policy, 2012

The goal of this Policy is "to create an enabling environment for the conservation in perpetuity, Kenya's rich diversity of species, habitats and ecosystems for the wellbeing of its people and the global community in accordance with the Constitution". Therefore, this policy seeks to protect, conserve and promote existence of wildlife resources whilst enhancing human wellbeing (RoK, 2012).

The policy outlines the following challenges facing Kenya's wildlife sector: *Loss of biological diversity* due to land use changes; *Land use change*: Changing land use particularly in agriculture and development (for example rural –urban development) affect wildlife migration due to land fragmentation. As a result, pathways traditionally used by wild life are blocked. This situation is exacerbated by lack of national land use policy and planning (RoK, 2012).

Destruction of wildlife habitats: Rapid population growth coupled with poverty and scarce environmental resources in unprotected land have stimulated encroachment into protected areas by populations. Continued encroachment into protected land by the ever-increasing population has seen wildlife migration patterns altered. In-addition, poor cultivation methods, deforestation, illegal charcoal burning, overgrazing and other unsustainable practices have contributed to degradation of wildlife protected sites. (RoK, 2012).

Other challenges include: Inadequate public private partnerships in the management of wildlife resources; In-adequate accurate scientific data; Illegal and unsustainable off-take of wildlife and

bush meat trade; Human Wildlife Conflict and Compensation; Pollution; Biopiracy; Climate change: Invasive alien species among others (RoK, 2012).

CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

3.1 Description of Study Site

3.1.1 Location

Meru National Park (MNP) is one of the oldest national parks in Kenya. The park is located in Meru North District and covers 870 km^2. It lies between $0^0$20'and 0^0 10'South, 38^0 00'and 38^0 25' East from the equator (Munyugi, Ruhiu and Warutere, 1996). MNP has the highest concentrations of wildlife in the Meru Conservation Area (MCA), as such it has traditionally been the focus of tourism and management in the MCA, and currently contains majority of park administration infrastructure such as roads, air strips and entrance gates.

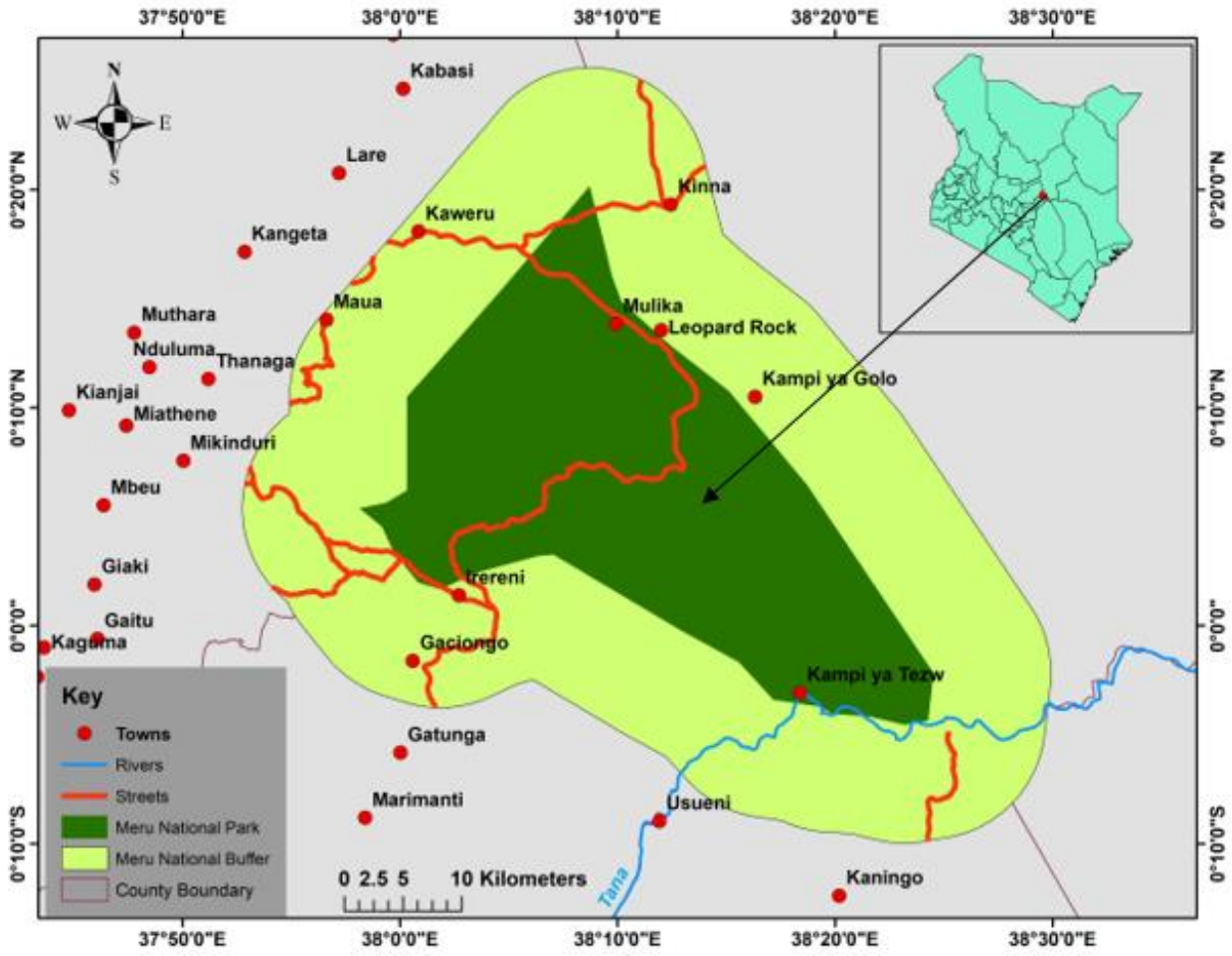


Figure 4:Location of MNP in Kenya

(Source: Author 2017)

3.1.2 Climate

MNP has a semi-arid eco-climatic zone with a bimodal rainfall pattern (Pratt & Gwynne, 1977). MNP receives moderate amounts of rainfall. The distribution of rainfall ranges from 300mm per annum in the lower midlands in the North to 2500mm per annum in the South East. Other areas receive on average 1250mm of rainfall annually. There are two rainy seasons with the long rains in March, April, May (MAM) and short rains from September to December (SOND). Temperatures range from a low of 8^{o}C to a high of 32^{o}C during the cold and hot seasons respectively. (Meru CIDP, 2013).

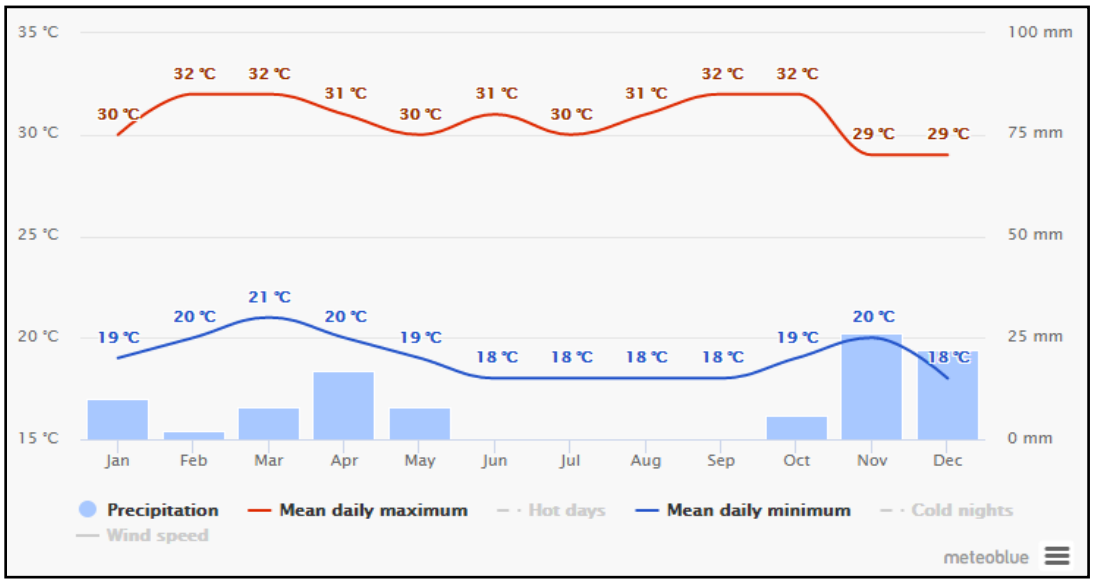


Figure 5:Climate of Meru National Park (Source: Meteoblue, 2017)

3.1.3 Physiography and drainage pattern

There are streams and rivers that drain through Meru National Park which are also bounded by several rivers namely: Ura, Rojeweru, Kathita, Bisanadi, and Mutudu. The streams that drain from the base of the Nyambene Hills are permanent. The Murera, Kathita, Kanjoo, Bwatharongi and Rojeweru rivers flow to the Tana which is the main river that drains into the Indian Ocean (Otuoma, 2005).

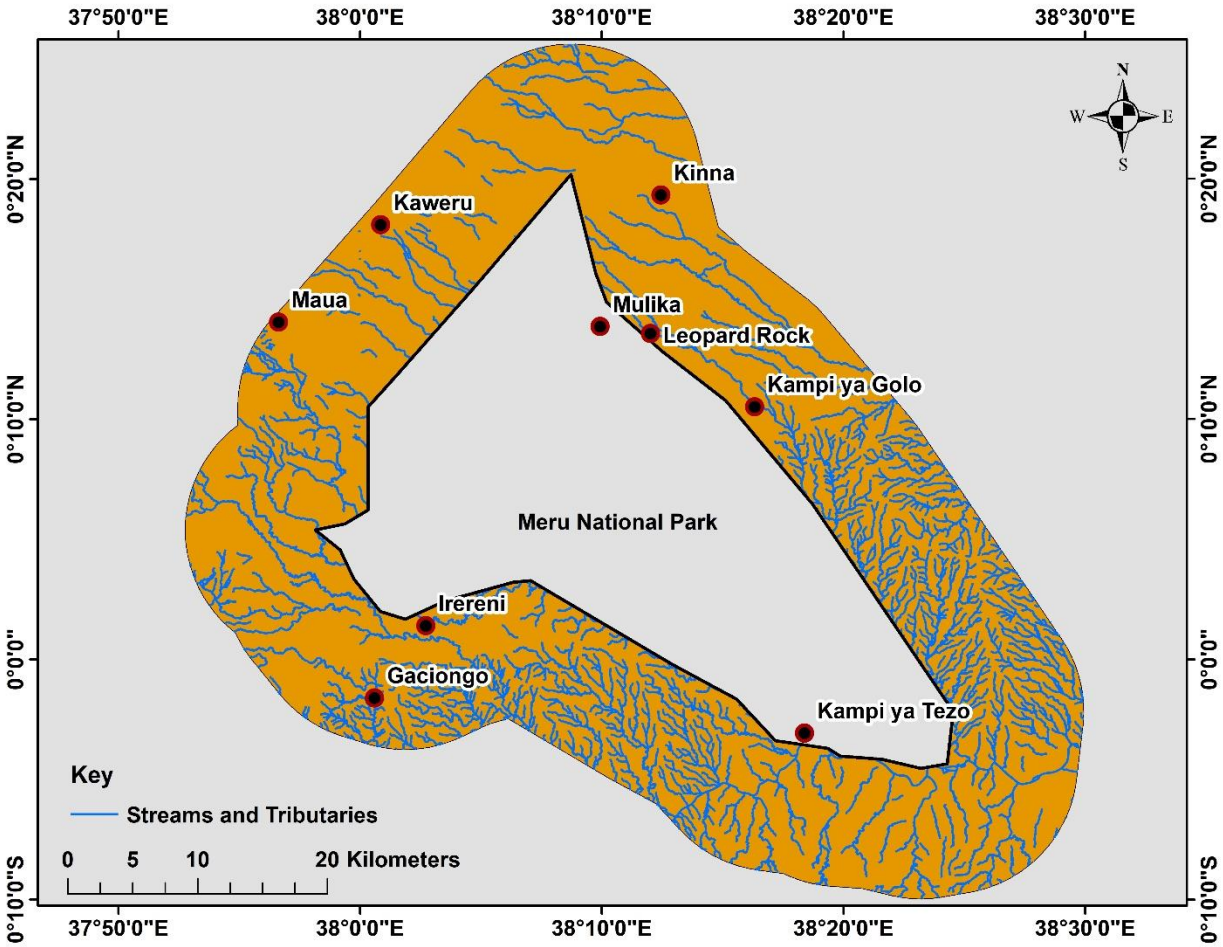


Figure 6: Drainage pattern of study area (Source: Author 2017)

The topography of the catchment area for water sources that drain into the park has an influence on the surface water flow and base flow. Streams flowing from the Nyambene hills generally have courses at right angles to the trend of the feature and the porous bedrock allows much of the drainage to flow beneath the surface and re-emerge in the park. The land flattens towards the east, where grey alluvial volcanic soils appear. This area is crossed by numerous permanent streams, draining from the Nyambene Hills and flowing in parallel between tongues of lava, south-eastwards towards the Tana River (Otuoma, 2005).

3.1.4 Ecology and vegetation cover

MNP is characterised by three main vegetation types namely: open acacia wooded grassland, bushland, and shrub land vegetation. The species that are dominant in these vegetation types are *Acacia Commiphora, Acacia Tortilis, Chloris, Acacia Mellifera, Acacia Seyal, Terminalia Brownii, Balanites Aegyptiaca, Tamarindus Indica, and Terminalia Spinosa.* The dominant grass species are *Chloris Gayana, Chrysopogon Plumulosus, Chrysopogon Roxyburghiana, Aristida Adscensionis and Sehima Nervosum.* (Pratt & Gwynne, 1977). In 1973, MNP was initially gazetted as a nature reserve and was later gazetted as national park in 1990. This was after the realisation of the need to ensure wildlife conservation. Owing to a marginal potential for rain-fed agriculture the adjoining community land is now under agro-pastoralism. although the continued immigration of agricultural communities in the area is increasingly putting the wetter margins exclusively under crop cultivation (UNESCO, 2010). Figure 7 illustrates the vegetation cover for the study area;

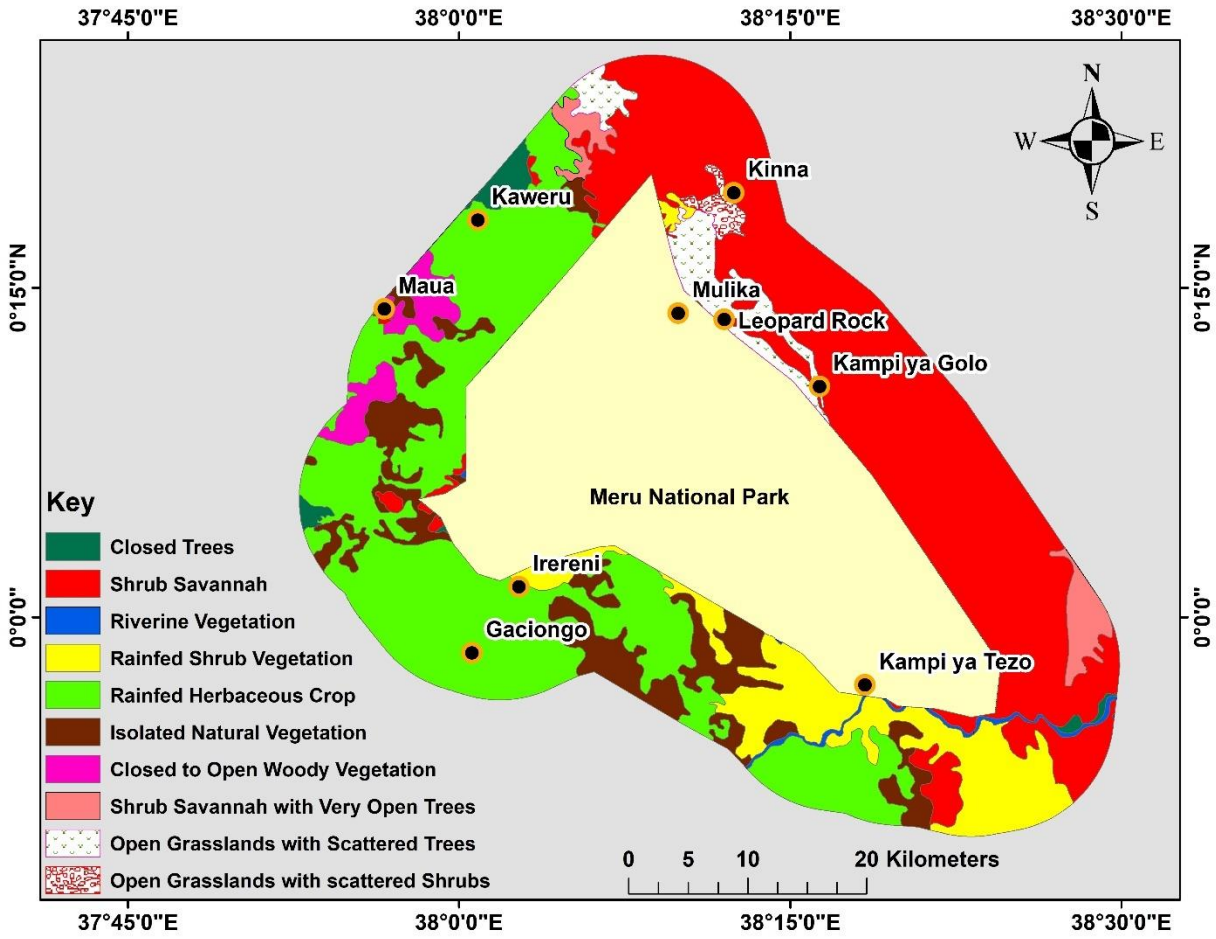


Figure 7: Vegetation types of study area

3.1.5 Geology and soil types

There are several prominent inselbergs of basement rock, notably Mughwango and Leopard Rock. The south and south-east (rainfall c. 300 mm per year) is an open, semi-arid plain with red lateritic soil with a number of streams crossing this area (Agwata, 2006). Figure 8 illustrates the geology of the study area.

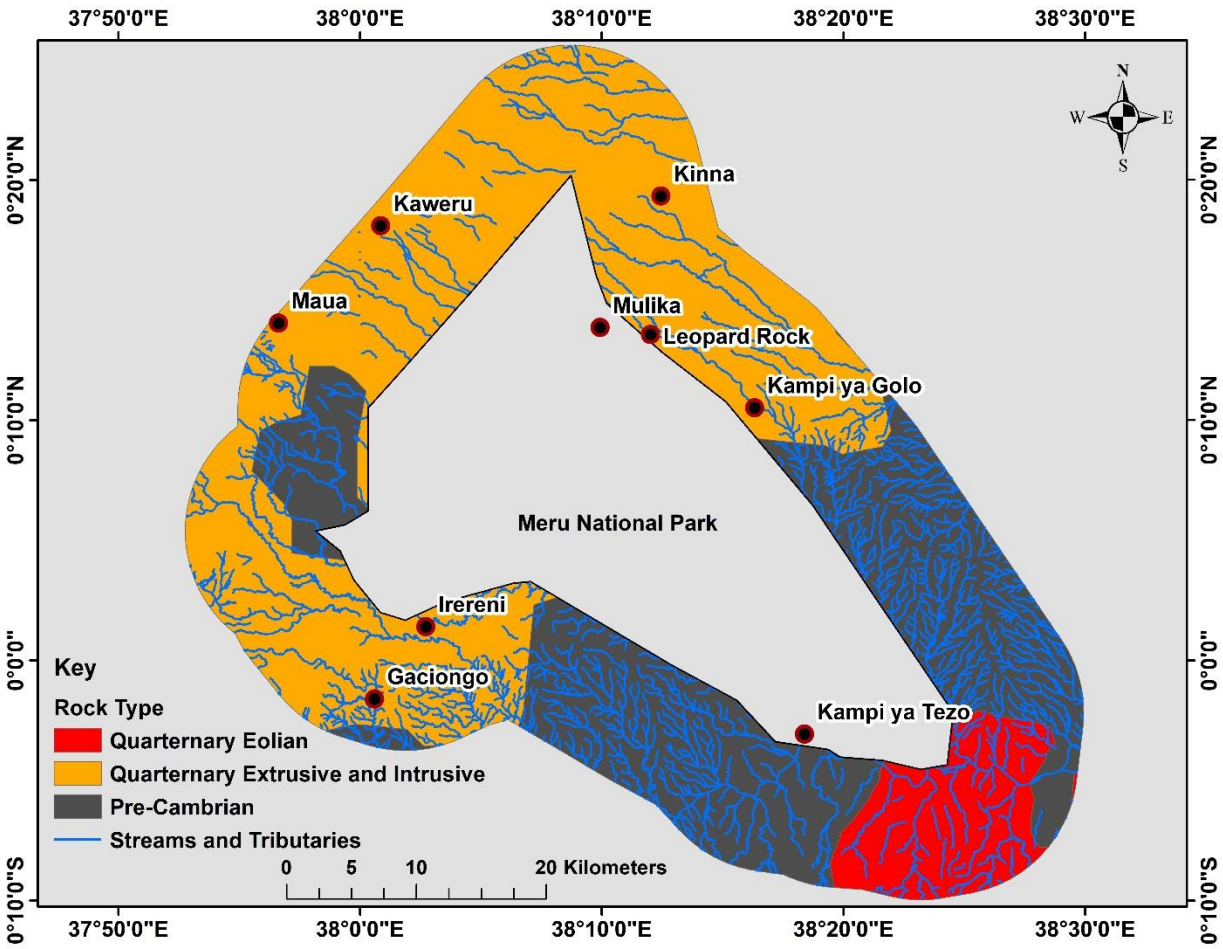


Figure 8: Geology of study area (Source: Author 2017)

Figure 9 illustrates the land use types of the study area. It is clear from the map that agricultural activity is concentrated on the northern, western and southern parts of the study area. This area has also been fenced by MNP to minimize human wildlife interactions.

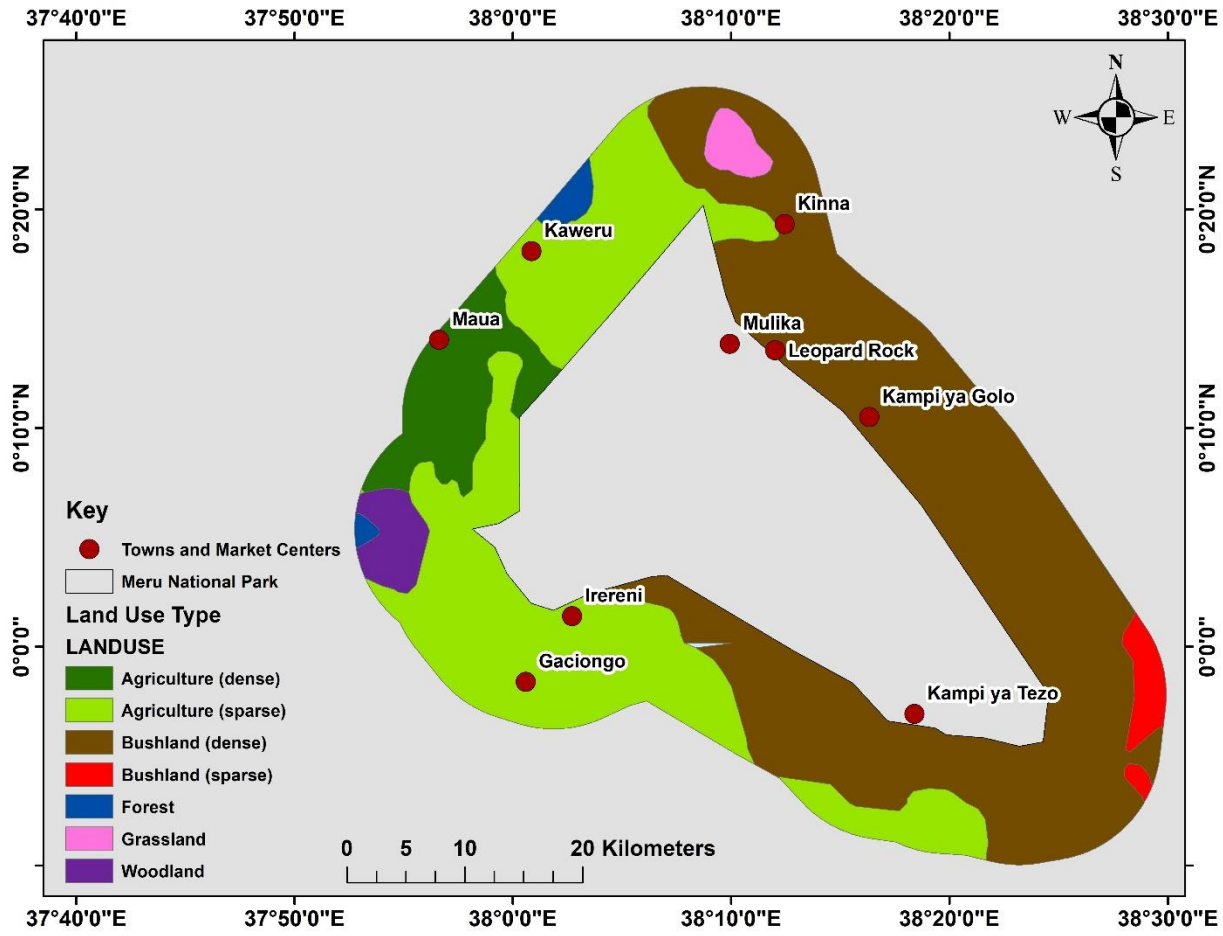


Figure 9: Land use types of the study area

3.1.6 Population and settlement

Meru Conservation Area (MCA) of which MNP is a part of recorded an 86% increase in human population as reported by the 2009 household census by the Kenya Bureau of Statistics. These statistics are for the six districts bordering the MCA which indicated an increase in human population from 1.56 million in 1979 to 2.90 million in 1999 (Kenya National Bureau of Statistics, 2001). Table 1 illustrates the population projections for the study area.

Table 1: Population projections by Constituency/Sub-county

Constituency	2009 (Census)			2012 (Projections)			2015 (Projections)			2017 (Projections)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Imenti South	90,291	89,313	179,604	96,100	95,059	191,158	102,282	101,174	203,456	106,623	105,468	212,091
Central Imenti	57,813	59,105	116,918	61,532	62,907	124,440	65,491	66,954	132,445	68,270	69,796	138,066
Tigania East	77,754	79,492	157,246	82,756	84,606	167,362	88,080	90,049	178,129	91,818	93,871	185,689
Imenti North	73,748	75,396	149,144	78,492	80,246	158,739	83,542	85,409	168,951	87,088	89,034	176,121
Igembe North	76,552	78,262	154,814	81,477	83,297	164,774	86,718	88,655	175,374	90,399	92,418	182,817
Igembe Central	95,627	97,765	193,392	101,779	104,054	205,833	108,327	110,749	219,075	112,924	115,449	228,373
Igembe South	66,532	68,018	134,550	70,812	72,394	143,206	75,368	77,051	152,419	78,566	80,321	158,887
Buuri	66,582	68,071	134,653	70,865	72,450	143,316	75,424	77,111	152,535	78,625	80,384	159,009
Tigania West	67,239	68,741	135,980	71,565	73,163	144,728	76,169	77,870	154,039	79,401	81,175	160,576
Total	**670,656**	**685,645**	**1,356,301**	**715,378**	**728,177**	**1,443,555**	**761,400**	**775,022**	**1,536,422**	**793,715**	**807,915**	**1,601,629**

Source: KNDS, 2009

3.2 Research Design

According to Burns and Grove (2003:195), research design is defined as a blueprint for conducting a study while maintaining the validity of the findings. The study applied both descriptive and exploratory research approaches. Burns and Grove (2003) describe a qualitative approach as "a systematic subjective approach used to describe life experiences and situations to give them meaning".

The rationale for choosing an exploratory research design was because of its flexibility for the researcher to consider different aspects of the problem under study and the rationale for choosing a qualitative research design was because it allows the researcher to explore the behaviour, perspectives, experiences and feelings of people and emphasise the understanding of these elements.

Based on the above rationales, this involved administration of socio-economic survey questionnaires to gain insights from communities around MNP on the effects of agricultural development around the park on biodiversity conservation. Exploration survey approaches were used to infer the effects of agricultural development on biodiversity conservation in areas surrounding MNP. Figure 10 gives an illustration of the research design that was adopted for this study;

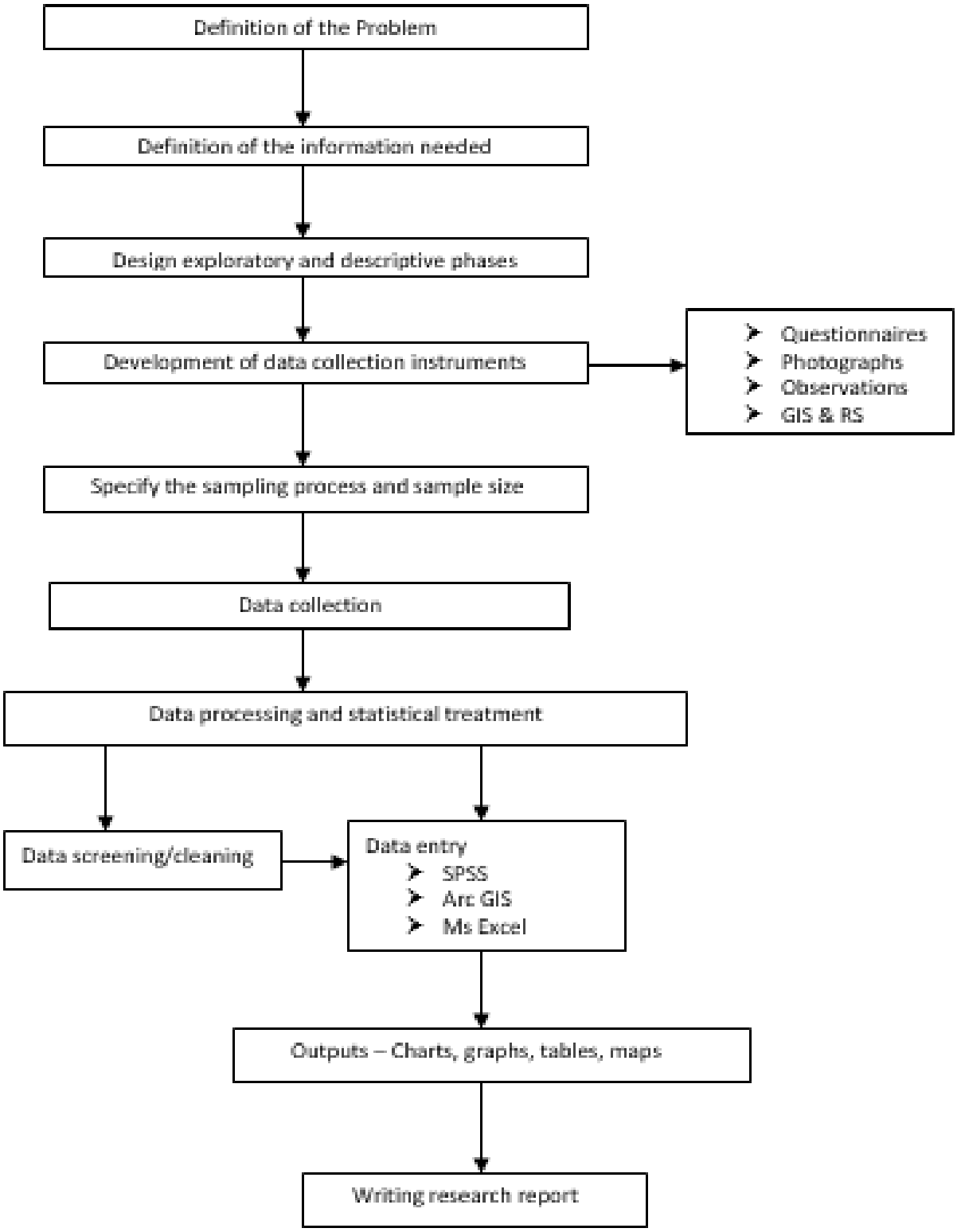


Figure 10: A summary of the Research Design (Source: Author, 2017)

3.2 Types and sources of data

3.2.1 Type of data

The data that was collected for this research targeted at ensuring that the objectives of this research were met. The data focussed on demographics related to social, economic and environmental needs of the community residing in MNP's buffer zone. The data also focussed on the policy, regulatory and institutional frameworks governing MNP, community-based conservation initiatives and integrated biodiversity management approaches being implemented. All the above listed data was put in the context of agricultural development in the study area.

3.2.2 Primary data

Primary data was used to inform preliminary findings of the research. Primary data was obtained from questionnaires (household and structured questionnaires), key informant interviews, and GIS imagery of the study area. The researcher administered the above listed data collection tools to the target population to obtain data on respondents' gender, age, level of education, source of livelihood, average monthly income, source of water for agricultural use, land ownership, types of crops cultivated, size of farms and farmers' future developments on the farms.

This was followed by data cleaning and processing, a process that enabled the researcher to detect and correct (or remove) any inaccurate records from the database. Incomplete, incorrect, inaccurate and irrelevant parts of the data were identified and corrected to give a true reflection of the situation on the ground. Data entry and analysis was done using the Statistical Package for the Social Sciences (SPSS). Data analysis included inspecting and transforming the obtained data with the goal of discovering useful information, suggesting conclusions, and providing statistics to support decision-making. The analysed data was interpreted through the generation of graphs and charts that have been included in this study report.

The Household questionnaires targeted households around the park boundaries of MNP within a 10km range from the park boundary and was based on people's perceptions. The information

collected related to livelihood activities for the adjacent communities, biodiversity conservation activities of the community to support MNP initiatives, and demographic data.

The structured questionnaires were administered to officers in MNP, WRMA, KFS, and Meru County government for the purpose of gathering information on biodiversity conservation as well as agricultural development in the study area.

GIS imagery was used to generate satellite imagery for land use changes over the years for areas adjacent to the park. All this information was used to give a better understanding of the impacts of agricultural development on biodiversity conservation in MNP.

3.2.3 Secondary data

Secondary data was used to compliment the primary data that was obtained. Secondary data on biodiversity numbers & population, water use statistics, forest cover statistics, human population, livestock population and environmental regulation statistics was obtained from various published and unpublished reports which include but was not limited to the following; KWS (HWC data, community based conservation projects, LULC change maps); Water Resources Management Authority (WRMA) (water abstraction permits, monitoring water abstraction); Kenya Forestry Service (KFS) (community conservation projects, firewood collecting permits); Kenya open data portal (human population demographics); ministry of agriculture, livestock and fisheries (acreage under agriculture, livestock demographics, policy and regulatory framework, implementation frameworks); ministry of environment, natural resources and regional development authority(MENR&RDA) (policy and institutional frameworks in biodiversity conservation, implementation frameworks); Kenya National Bureau of Statistics (KNBS) (human population census results); Regional Centre for Mapping of Resources for Development (RCMRD) (wildlife dispersal and population maps); National Environment Management Authority (NEMA) (water abstraction permits and monitoring); and International Union for Conservation of Nature (IUCN) (livestock population in MNP buffer zone). Other peer published reports and government reports on biodiversity conservation were reviewed to enrich the study.

3.3 Sample size

Bartlett, II *et al* (2001) argue that the common goal of survey research is to collect data which is representative of a population. They note that a researcher uses information gathered from the survey to generalize findings from a drawn sample back to a population, within the limits of random error.

Peers (1996) argues that determining the correct sample size is one of the four inter-related features of a study design that can influence the detection of significant differences, relationships or interactions. Yamane (1967:886) provides a simplified formula to calculate sample sizes. This formula was used to calculate the sample size with the aim of determining an adequate sample size to estimate the population prevalence with a good precision;

$$n = \frac{NC_V^{\,2}}{(C_V^{\,2} + (N-1)\,e^2)}$$

Where P, confidence level of 95% = 0.5

n = sample size,

N = population size,

e = level of precision, take 0.05 at 95% confidence level

C_V = coefficient of variation = 0.5

From the 2009 census by Kenya National Bureau of statistics, Meru County had a population of 1,365,301 people hence N= 1,365,301. Applying the formula above;

Therefore, $n = \dfrac{1{,}365{,}301\ (0.5^2)}{0.5^2 + (1{,}365{,}301 - 1)\ (0.05^2)}$

$= 99.99$

Therefore, n = 100 respondents

3.4 Sampling procedure

Cochran (1977) states that a sampling procedure is the process of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population.

Informed by the study objectives and the desired data sets, purposive sampling was used in identification of households to be interviewed as well as for officials in the County government, Kenya Wildlife Service (KWS), Water Resources Management Authority (WRMA), Kenya Forestry Service (KFS), Ministry of Agriculture, Livestock and Fisheries; Ministry of Environment, Natural Resources and Regional Development Authority (MENR&RDA) and National Environment Management Authority (NEMA).

The aim of this was to target the officers who are in charge of biodiversity conservation as well as agricultural development. The researcher gathered more information regarding policies and institutions that are tasked with biodiversity conservation as well as the on-going government initiatives in addressing this subject.

3.5 Methods of data collection

The researcher applied both qualitative and quantitative methods of data collection.

3.5.1 Qualitative research

Qualitative research was used to gain an understanding of underlying reasons, opinions, and motivations. It provided insights into the problem by unearthing ideas or hypotheses for potential quantitative research. This was also used to uncover trends in thought and opinions of the respondents. Observation was used to gather data by watching behaviour, events, or noting physical characteristics in their natural setting. Face-to-face interviews were employed to uncover statistics relevant to the study objectives from the respondents.

3.5.2 Quantitative research

Quantitative research was used to quantify the problem by way of generating numerical data or data that was transformed into useable statistics. It was used to quantify attitudes, opinions, behaviors, and other defined variables as well as generalizing results from a larger sample population. Observation was used to gather data by watching behaviour, events, or noting physical

characteristics in their natural setting. Face-to-face interviews were employed to uncover statistics relevant to the study objectives from the respondents.

3.6 Instruments of data collection

The following instruments were used for data collection for this research.

3.6.1 Questionnaires

Household questionnaires were used for the household survey which targeted households that are situated in MNP's buffer zone - at least 10km radius from the park boundary. The questionnaires were used to gather socio-economic information on; gender, education level, types of livelihood activities, monthly income per household, land ownership, size of farms, type of crops cultivated and sources of water for agricultural use.

Data on education level was used to determine the farming methods that are being adopted on the farm i.e. irrigation, organic manure, inorganic manure and green houses. Data on gender was used to determine the gender type that dominated farming activities and their vulnerability to have interactions with wildlife while on the farms. Data on type of crops cultivated was used to estimate water and farm input needs as well as frequency of farming i.e. perennial, biennial etc. Data on land ownership, size of farm and planned developments on the farm was used to determine land fragmentation in the study area. Data on type of crops grown and duration of farming was used to determine the impacts of land use changes on community-based conservation. The household questionnaire used is illustrated in appendix IV.

Structured questionnaires administered through key informant interviews were also used to interview government and parastatal officials in the selected offices to gather information on HWC, policy and institutional frameworks, capacity needs assessment, challenges and opportunities for collaboration with other stakeholders in community-based biodiversity conservation and management. The research targeted technical personnel in conservation and environment departments which included, environment officers at the County level; scientists and community officers at KWS; environment and water (abstraction) sector officers at WRMA;

community development officers at KFS; agriculture and livestock officers at MENR&RDA and water abstraction monitoring officers at NEMA. The key informant interview guide that was used is illustrated in appendix III

3.6.2 Spatial Analysis and Geographic Information System (GIS)

Spatial analysis is an integral process when exploring the land use and land cover changes of a specific location. Four time-period data sets were used for this study (2000, 2005, 2010 and 2016). Overlay analysis was executed on these layers for detecting land use changes in the study area. Visualisation of the analysis results was considered as another important element of the study. Thematic maps showing the changes in land use patterns for agricultural development and showing the direction of extension for farm lands was designed to better understand the results of the study.

According to Salem (2003), GIS systems can be used to effectively overlay maps of the ranges of endangered plant and animal species onto maps of habitat areas which gives a researcher a refined scenario of the challenges of biodiversity conservation in an area of interest. Salem (2003) also argues that by using GIS maps, conservationists and wildlife managers can visualize and present suitable data to optimize the boundaries of reserves during their creation, so as to achieve the highest rate of biodiversity preservation in the complex negotiations necessary to balance social and economic needs with habitat and species conservation.

As the application of choice for this research, GIS played a central role in analysing land use changes since it has become so widely established in biodiversity conservation (Krigas, Papadimitriou, & Mazaris, 2012).

GIS was used to determine the specific land use changes that have occurred over time in the study area as well as the extent of the transformation. Change detection maps of the Study area were generated from Satellite images obtained from Google Earth (Google, 2017). Google Earth was the program of choice for this study because it provides the latest high-resolution satellite imagery and is readily visualized with tools available in most popular image processing and GIS software such as ArcGIS, ENVI, and ERDAS IMAGINE.

3.6.3 Photographs

According to Bateson and Mead (1942), photographs have been used in research for a long time in various sub disciplines such as scientific and social sciences as a method of generating theory. Harper (1998) suggests that photographs can be used in several ways including: studies of interaction; the presentation of emotion; the elicitation of information in interviews; and studies of material culture.

In this study, photographs were used to document the current situation on the ground such as the farming methods being used by the farmers, water abstraction practices from water sources and pastoral activities in the study area. Photographs were used to compliment the data obtained from the questionnaires by giving visual evidence of the situation on the ground.

Chapter 2 3.7 Data analysis methods

Both qualitative and quantitative techniques were used to analyse the collected data. The quantitative techniques were done through coding the data from questionnaires based on broad thematic areas. This was followed by analysis using the Statistical Package for Social Science (SPSS). A substantial part of the data entry and analysis was based on descriptive statistics tools such as frequencies, graphs and cross-tabulation.

Data cleaning and processing, a process that enabled the researcher to detect and correct (or remove) any inaccurate records from the database was conducted. Incomplete, incorrect, inaccurate and irrelevant parts of the data were identified and corrected to give a true reflection of the situation on the ground. Data entry and analysis was done using the Statistical Package for the Social Sciences (SPSS). Data analysis included inspecting and transforming the obtained data with the goal of discovering useful information, suggesting conclusions, and providing statistics to support decision-making. The analysed data was interpreted through the generation of graphs and charts that have been included in this study report

The above statistics were used to determine and to examine the following aspects: impact of agricultural development on biodiversity conservation in MNP, type and impact of land use

changes that have occurred on community-based conservation and the size and extent of human wildlife conflicts in MNP's buffer zones. Proportions and percentages have been used to make general inferences. This analysis was used to draw conclusions. Data presentation has been done by the use of graphs, charts and maps.

3.7.1 Spatial analysis

Spatial analysis is a type of geographical analysis which seeks to explain patterns of human behaviour and its spatial expression. Spatial analysis is an integral process when exploring the land use and land cover changes of a specific location. Jenson (1986) recommends that to be able to detect land use and land cover changes over time, at least two time-period data sets should be used. Overlay analysis was executed on these layers for detecting land use changes in the study area. Visualisation of the analysis results was considered as another important element of the study. Thematic maps showing the changes in land use patterns for agricultural development and showing the direction of extension for farm lands was designed to better understand the results of the study.

CHAPTER FOUR
DATA ANALYSIS, DISCUSSION AND PRESENTATION

4.0 Chapter overview

This chapter presents the findings of the study and discussion of the results as per the data collected from the field. The findings are presented in relation to the study objectives. Section one provides information on land use and land cover changes that have occurred in the study area as a result of the increased agricultural activities and how this is impacting on biodiversity conservation. Section two provides information on socio-economic activities of the community and how this affects biodiversity conservation. Section three provides information on agricultural activities for both farming and pastoralism and how these impact on biodiversity conservation.

4.1 Vegetation analysis using Google Earth imagery

Google Earth is a program that runs on a desktop computer and renders a 3D representation of the Earth based on a collection of satellite imagery. The program maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and GIS data onto a 3D globe, allowing users to see cities and houses at various angles. Google Earth allows users to search for addresses for some countries and enter coordinates.

Change detection maps of the Study area were generated from Satellite images obtained from Google Earth (Google, 2017). Google Earth was the program of choice for this study because it provides the latest high-resolution satellite imagery and is readily visualized with tools available in most popular image processing and GIS software such as ArcGIS, ENVI, and ERDAS IMAGINE.

The Google Earth desktop application has a data repository of processed satellite images acquired over a period. This makes it easy to study land cover changes of a particular place on a temporal scale. The main disadvantage in using Google Earth is the fact that it does not allow the use of original multispectral band data and therefore doesn’t have spectral signatures image classification

using unsupervised or supervised techniques. Yet since the spatial resolution is very high, it is possible to visually see on the image key features and on-screen digitizing in GIS can easily be performed to detect any changes (Malarvizhia *et al*, 2016). Google Earth dataset was obtained from https://www.google.com/earth/download/ with spatial resolution of less than 1m.

4.2 Image Analysis

The Google Earth desktop application was preinstalled in a desktop computer and made the default application for reading and writing. kml file types. A. kml file of the Study area was prepared in ArcMap 10.5 by converting MNP.shp to MNP.kml using the data conversion tool. MNP.kml was opened in Google Earth to make observations of the Study area. Using the Time slider tool while panning through the image of the Study area revealed substantial changes that occurred between 2000 and 2016. The initial observation helped to sample out the areas of interest to focus on human activities. This focus area included the farms near Kampi ya Tezo and the closed forest near Kaweru market center as shown in figure 11. Saved images were imported into ArcMap for Georeferencing and digitizing to generate vector data.

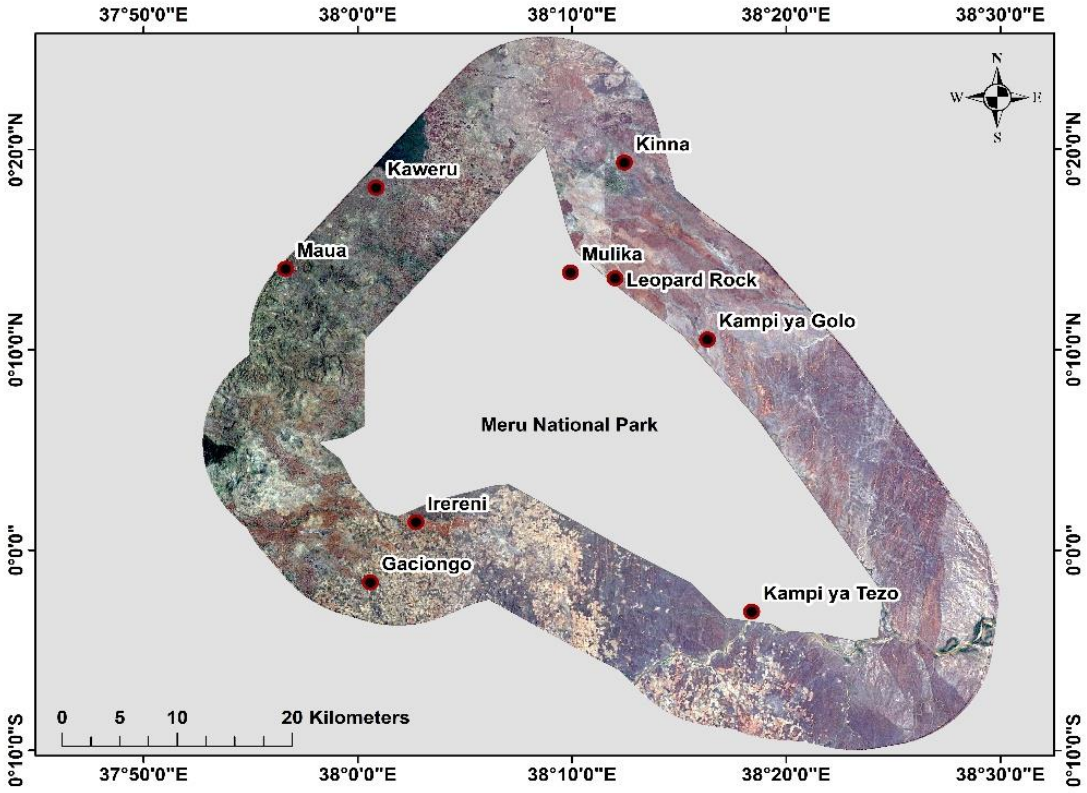


Figure 11: Satellite Image of MNP Buffer in 2000. Source: Google Earth 2017

Process Illustration

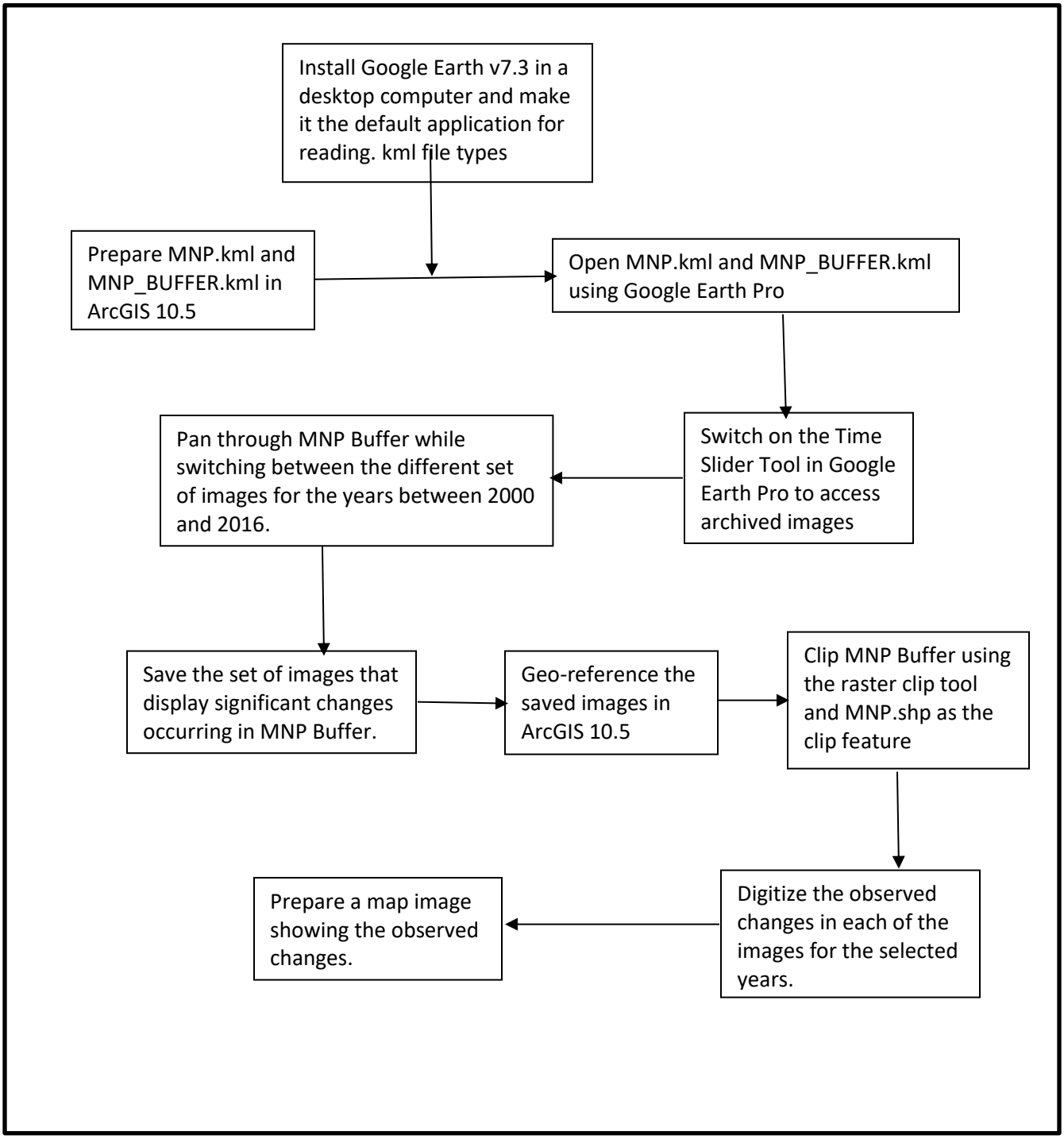


Figure 12: An illustration of the image analysis process

4.2.1 Land cover change

Figure 13 is a vegetation map of MNP Buffer zone. A substantial area is covered by shrub savannah. Much of the farming takes place in the area covered by rain-fed herbaceous vegetation.

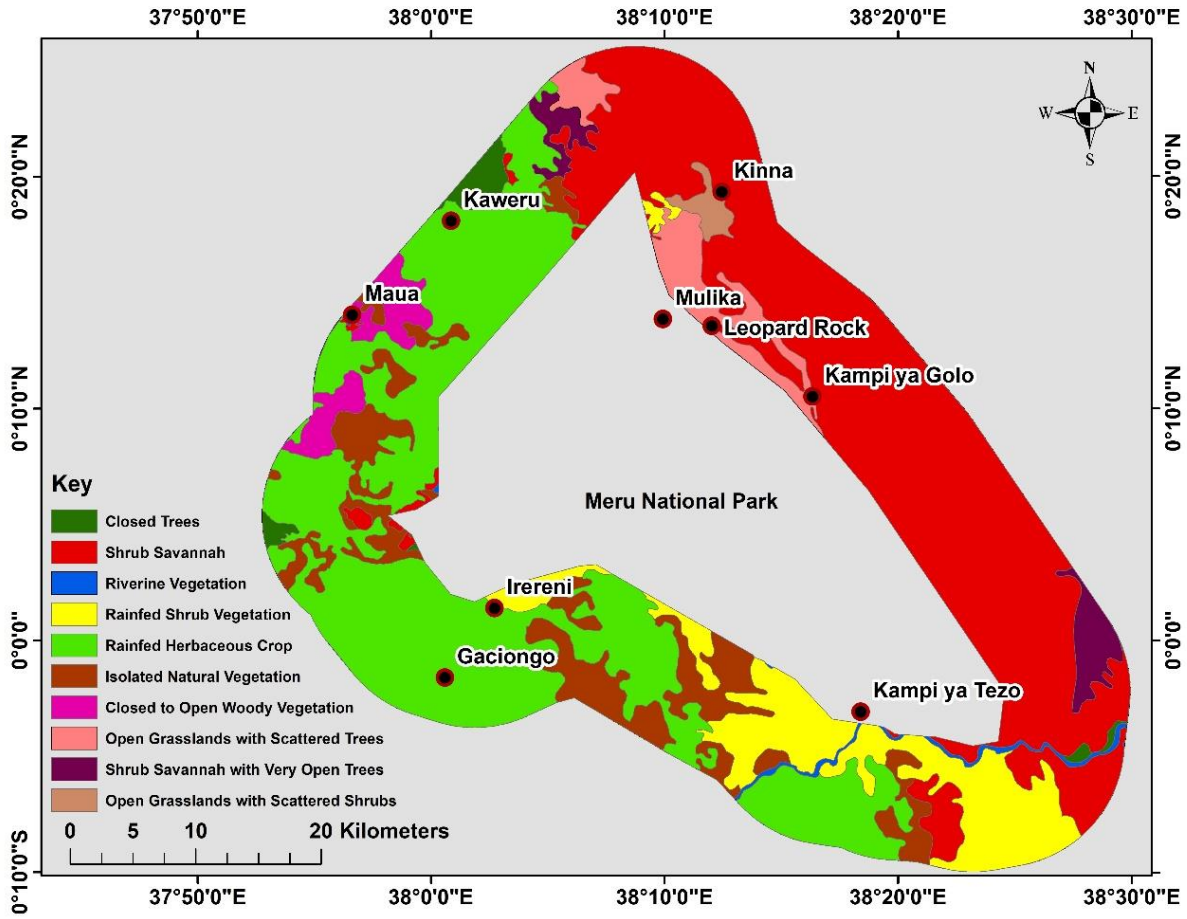


Figure 13: Vegetation map of in MNP Buffer in 1998. Source KU GIS Lab, Researcher 2017.

The results of the image analysis indicate a significant reduction in the area covered by rain-fed shrub vegetation. The results also indicated that the area covered by closed trees near Kaweru trading centre increased albeit slightly.

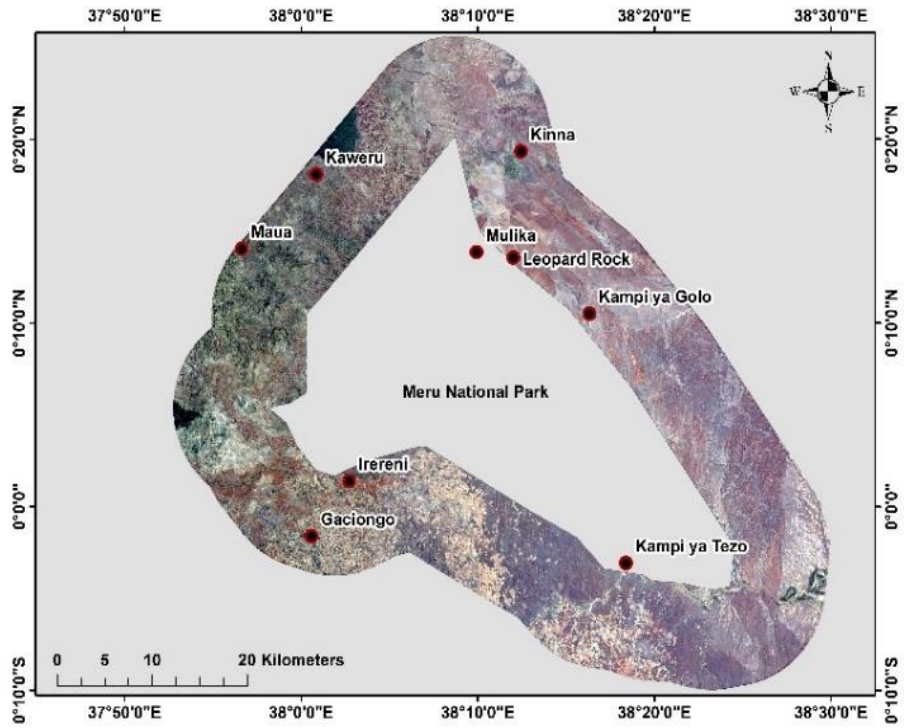
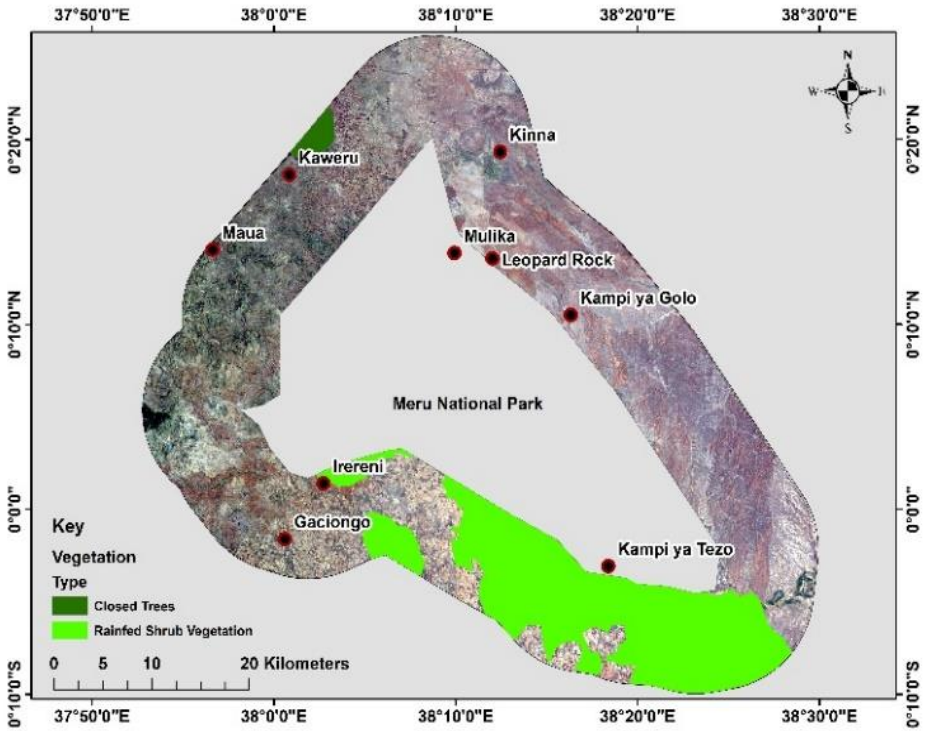
2000	Baseline Data
	

Figure 14: On the left is the image of MNP Buffer in 2000 while the right is the map image of the same time with the layer of rain-fed shrub vegetation overlaid. Image Courtesy of Google Earth and KU GIS Lab.

In figure 14, the rain-fed shrub vegetation near Kampi ya Tezo is coloured in light green while the area covered by closed trees near Kaweru market centre is coloured in dark green. The set of images presented formed the baseline information for image analysis.

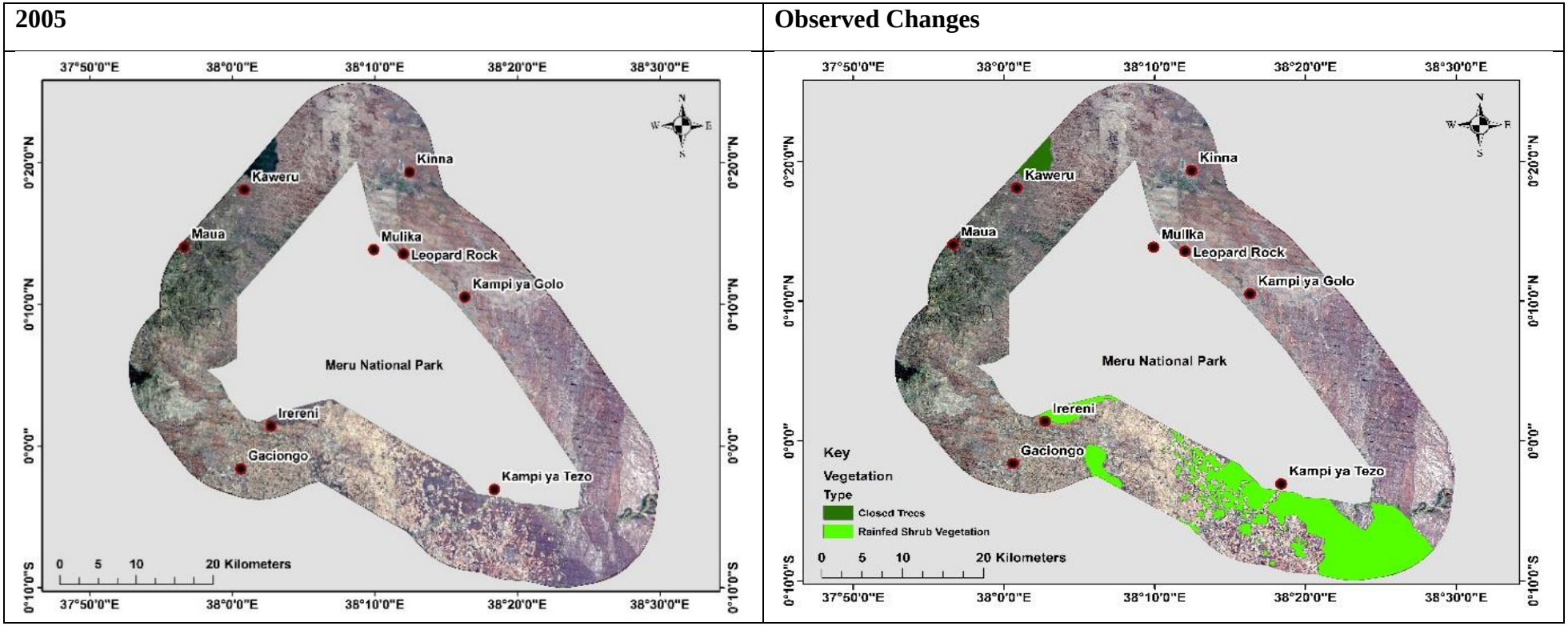


Figure 15: Satellite Image of MNP Buffer in 2005 while on the right is the map showing the observed changes overlaid on the image

Figure 15 shows a significant reduction in the area covered by rain-fed shrub vegetation. Much of the reduction takes place between Gaciongo and Kampi ya Tezo. The area covered by closed trees near Kaweru market center increases slightly.

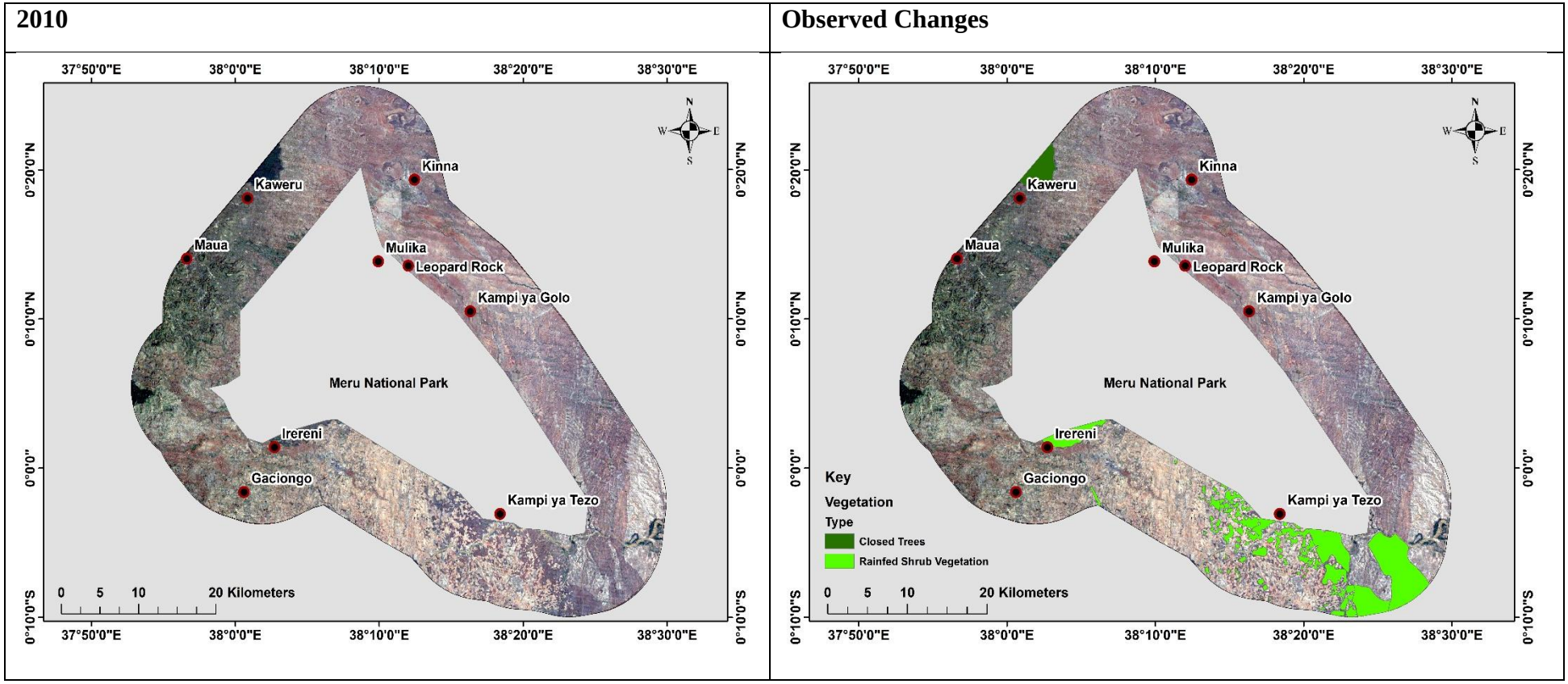


Figure 16: Satellite image of MNP Buffer in 2010. On the right is areas covered by rain-fed shrub vegetation and closed trees in light green and dark green respectively. Source Google and KU GIS Lab.

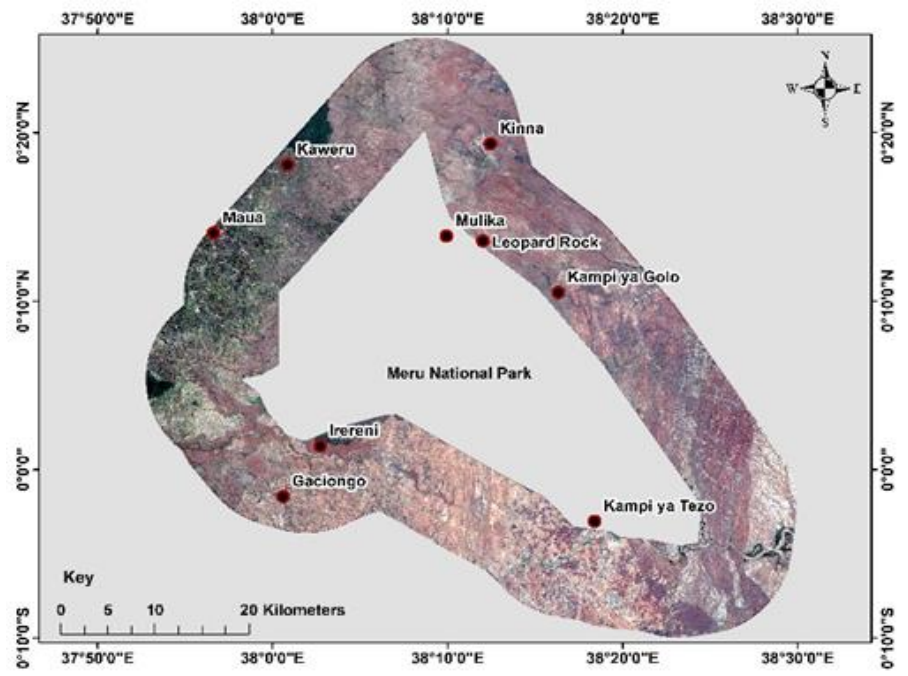
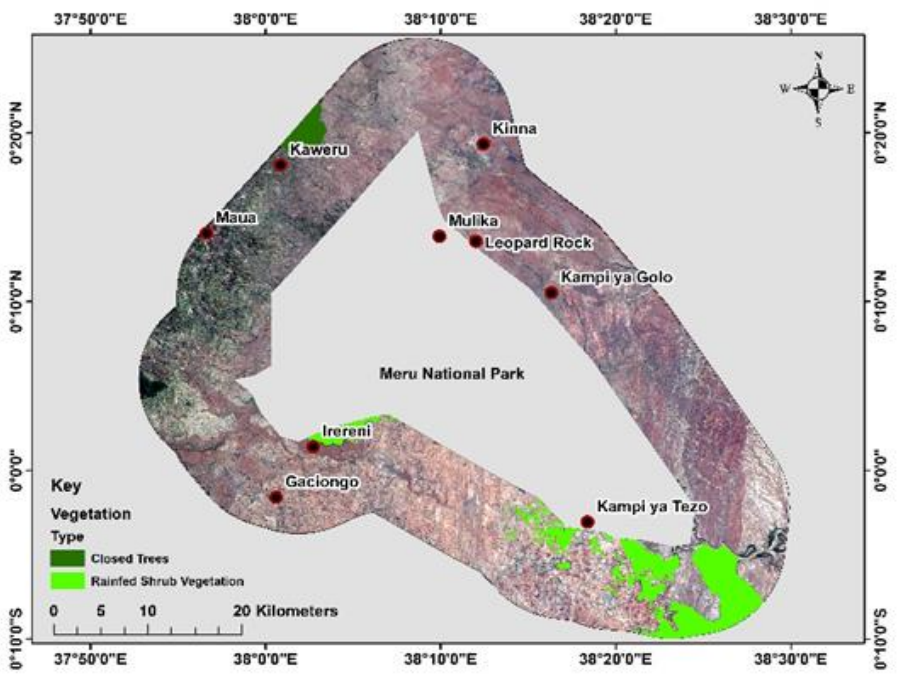
2016	Observed Changes
	

Figure 17: Satellite Image of MNP Buffer in 2016 and on the left, is the respective map image showing the observed changes. Image courtesy of Google and KU GIS Lab.

4.2.2 Discussion

The area under rain-fed shrub vegetation reduced significantly by 66.69 km^2 between 2000 and 2016 as shown in Table 2. This is attributed to the clearing of the shrubs to set up farms.

Table 2: Percentage change in rain-fed shrub vegetation from baseline year

Year	Rain-fed Shrub (area in square km)	Closed Trees (area in square km)
2000	248.44	11.21
2005	183.26	11.24
2010	102.13	11.65
2016	82.76	12.02
% change from baseline	-66.69	+7.2

4.3 Socio-economic activities of the respondents

The following section gives a summary of the socio-economic dynamics in the study area. This section covers gender, education level, types of livelihood activities, monthly income per household, land ownership, size of farms, type of crops cultivated and sources of water for agricultural use.

4.3.1 Gender of respondents

Incidences of HWC indicate that there are more female victims as compared to males. This can be related to the fact that women are more involved in farm activities and are thus exposed to HWC in the study area. Baboons have particularly been reported to attack female victims in the study area. Incidences of male victims have been reported for off farm activities like herding. This has happened when pastoralists let their animals to herd inside the park illegally. These incidences are lower in number compared to those of female victims being attacked on farms.

Majority of the respondents, 57%, were female respondents while 43% were male respondents. This is an indication that women are more involved in agricultural activities on farms than men in

the study area, a situation that pre-disposes them to interaction with wild animals while on the farms. The statistics obtained were used to determine the size and extent of HWC in the study area.

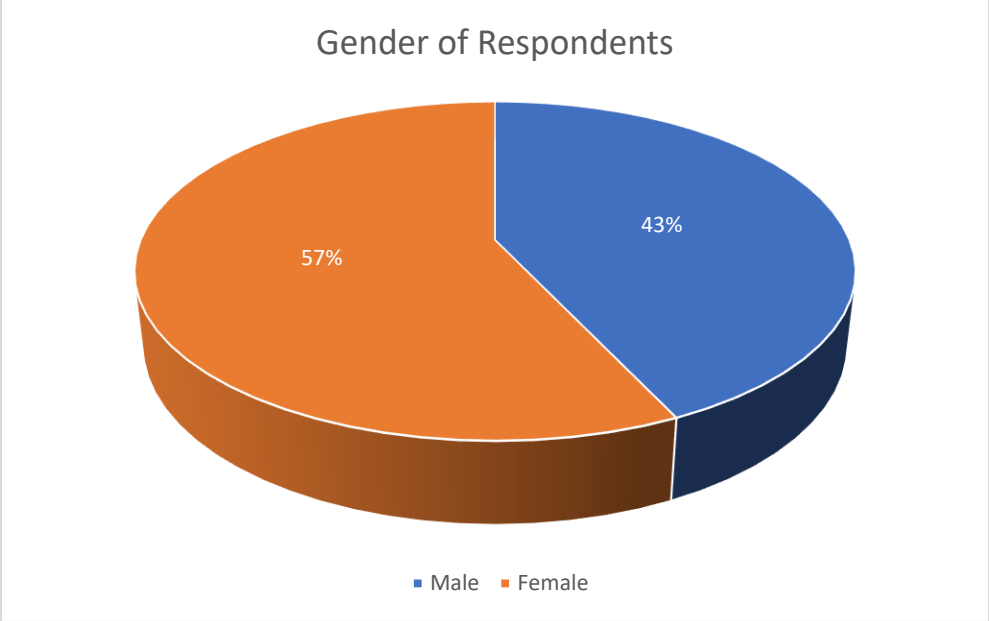


Figure 18: Gender of respondents (Source: Field data 2017)

4.3.2 Age of respondents

The age of respondents was important in revealing the type of farming methods used as well as future plans of the farmers living adjacent to the park. Respondents aged between 18 and 40 are likely to continue farming in the next 30 years which gives an indication of the number of farmers in years to come. This affects land fragmentation patterns and type of crops grown as the farmers sub-divide their pieces of land for inheritance of their dependants. Majority of the respondents, 34%, engaging in agricultural activities are aged between 41 and 50 years. This group of farmers own the ancestral land and can expand their farming because they have relatively larger pieces of land.

Respondents aged between 31 and 40 years with 27% representation are mostly immigrants who have settled in the stud area. A few of the respondents, 12%, are aged between 19 and 30 years. Only 6% of the respondent are 60 years old and above.

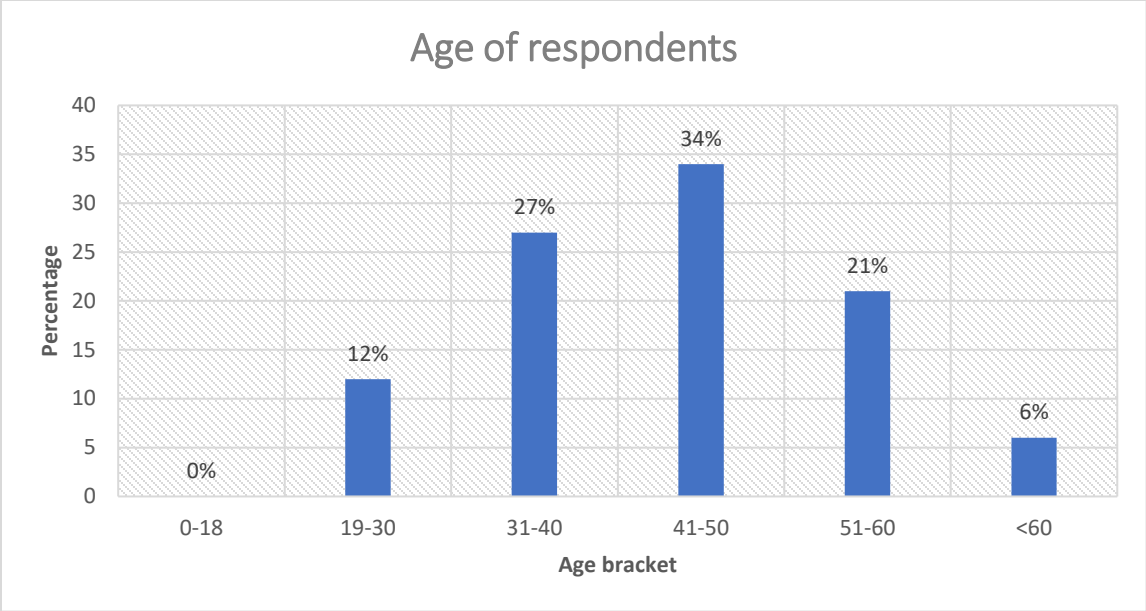


Figure 19: Age of respondents (Source: Field data 2017)

4.3.3 Level of education

The level of education attained by the community living adjacent to the park is directly related to their attitudes towards community-based biodiversity conservation. Respondents with advanced education i.e. college and university degree were more aware of the need to conserve biodiversity because of the role it plays in maintaining a stable ecosystem. This factor indicates the involvement in community-based conservation activities for community members with advanced education i.e. college and university degree These farmers were also engaging in efficient technologies of farming such as drip irrigation to conserve water from the streams and to ensure that some water reaches the park for wildlife consumption. Farmers with lower levels of education i.e. secondary and primary are engaged in traditional techniques of farming (rainfed agriculture).

Respondents with advanced education also indicated their willingness to be more involved in community-based conservation and community policing for law offenders such as in the case of poaching and vandalism of posts and wires from the electric fence surrounding the park. They also expressed their interest in stakeholder participation during policy and strategy formulation to ensure their role in community-based conservation is cemented by law.

Respondents with basic and no education expressed that the income received from participating in community-based conservation was very minimal and varies from project to project. This situation has led to most of them shifting to agricultural production for increased and steady income.

Majority of the farmers, 40% of the respondents, indicated that they had secondary level of education, these were mostly the elderly people in the community who own or inherited ancestral land. 32% of the respondents indicated that they had attained diploma level of education while 19% of the respondents indicated that they had attained university level education. Only 8% of the respondents had primary school level education.

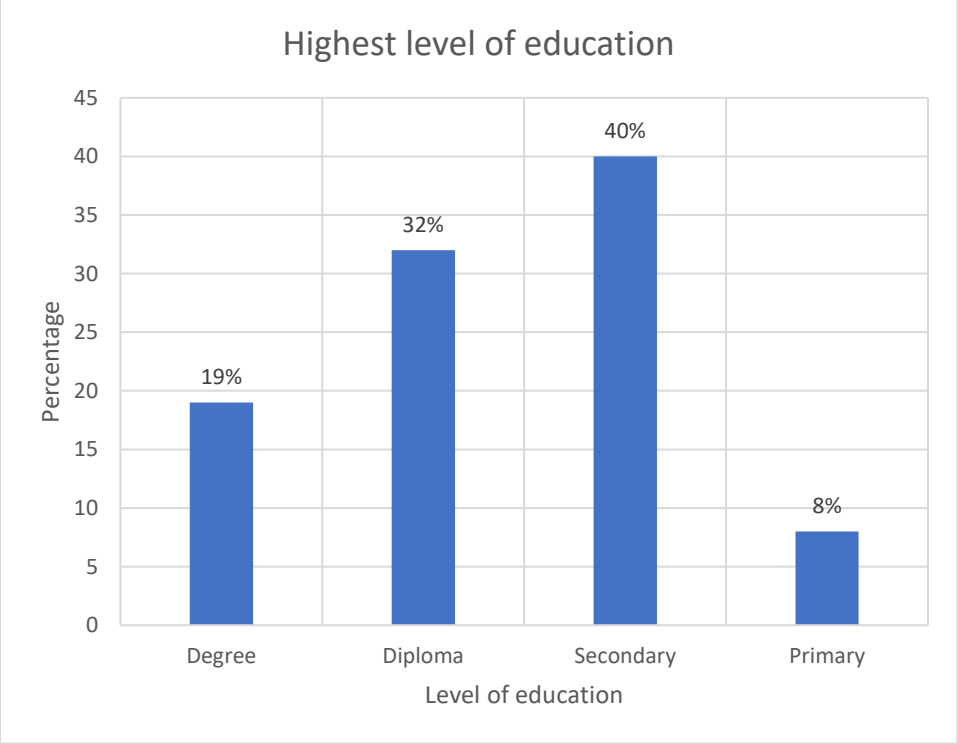


Figure 20: Level of education (Source: Field data 2017)

4.3.4 Prevalent source of livelihood

Intensified irrigated agriculture in the study area has resulted in serious water issues in the park. This is because most of the farming is occurring up stream of the rivers flowing into the park. This has greatly reduced the amount of water entering the park for wildlife to consume. As a result, wildlife travel long distances in search of water and greener pasture. The other sources of

livelihood i.e. rain-fed agriculture, pastoralism, trade and hunting have lower impact on the scarce water resources in the study area.

The prevalent source of livelihood for the respondents in the study area is irrigated agriculture which is 43% of total respondents. Pastoralism is also widely practiced with 28% of the respondents being involved in this activity. Some of the respondents, 15%, are involved in trade while 2% of the respondents are involved in hunting.

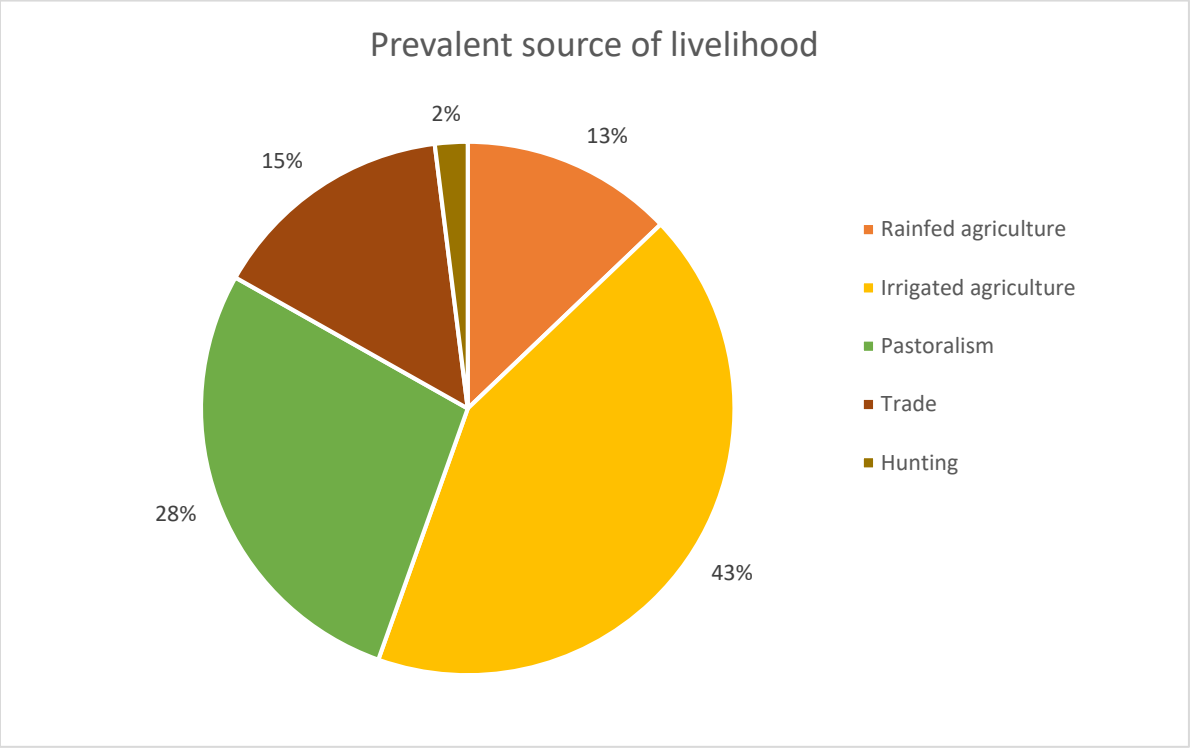


Figure 21: Prevalent source of income (Source: Field data 2017)

4.3.5 Main source of income

The main source of income in the study area is important in indicating the most preferred land use and natural resource use, specifically water resources, in the study area. The most prominent land use in the study area is farming, an activity that is usually accompanied with significant land use and land cover changes due to clearing of fields for farming. This change in land use has resulted in the community opting out of community-based conservation activities which they deemed time

consuming with low pay to concentrate on farming, an activity they indicated has better financial returns.

The main source of income is Khat (miraa) farming with 42% of the respondents engaging in this activity. The recent trend is irrigated Khat (miraa) farming to ensure production throughout the year. This irrigation has posed serious challenges for the scarce water resources such as streams and rivers in the study area. Miraa farming is also popular because of the high market value it has compares to other farm products such as maize and beans.

General farming is also practised by 22% of the respondents. Trade is another source of income in the study area with 20% of the respondents engaging in this activity. A small portion of the sample population, 16%, is involved in formal employment. Trade and formal employment do not have any recorded negative impacts on biodiversity conservation in the study area.

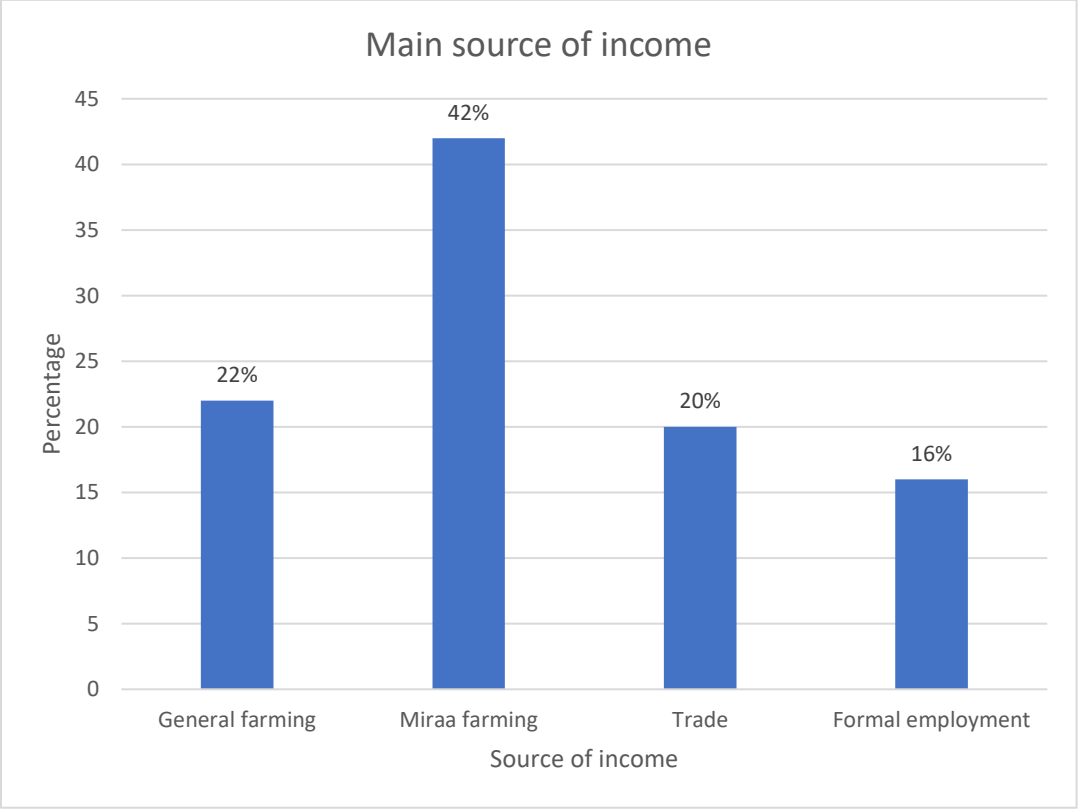


Figure 22: Main source of income (Source: Field data 2017)

4.3.6 Average monthly income

The average monthly income of respondents in the study area is important in giving an indication of the ability of a household to sustain its needs including ability to purchase water abstraction permits and farming inputs. It was revealed that law offenders/poachers who have been engaged in anti-conservation activities such as poaching and vandalism in the study area are in search of higher income to be able to take care of their families.

The average monthly income of the respondents in the study area is between 10,001 to 30,000 Kenya shillings. 32% of the respondents make between 5,001 to 10,000 Kenya shillings in monthly income. Another 12% of the respondents make more than 30,000 Kenya shillings in monthly income. The remaining portion of the population 5% and 3% make between 2,001 to 5,000 Kenya shillings and less than 2,000 Kenya shillings in monthly income. The above statistics indicate that majority of the families in the study area make minimal incomes monthly.

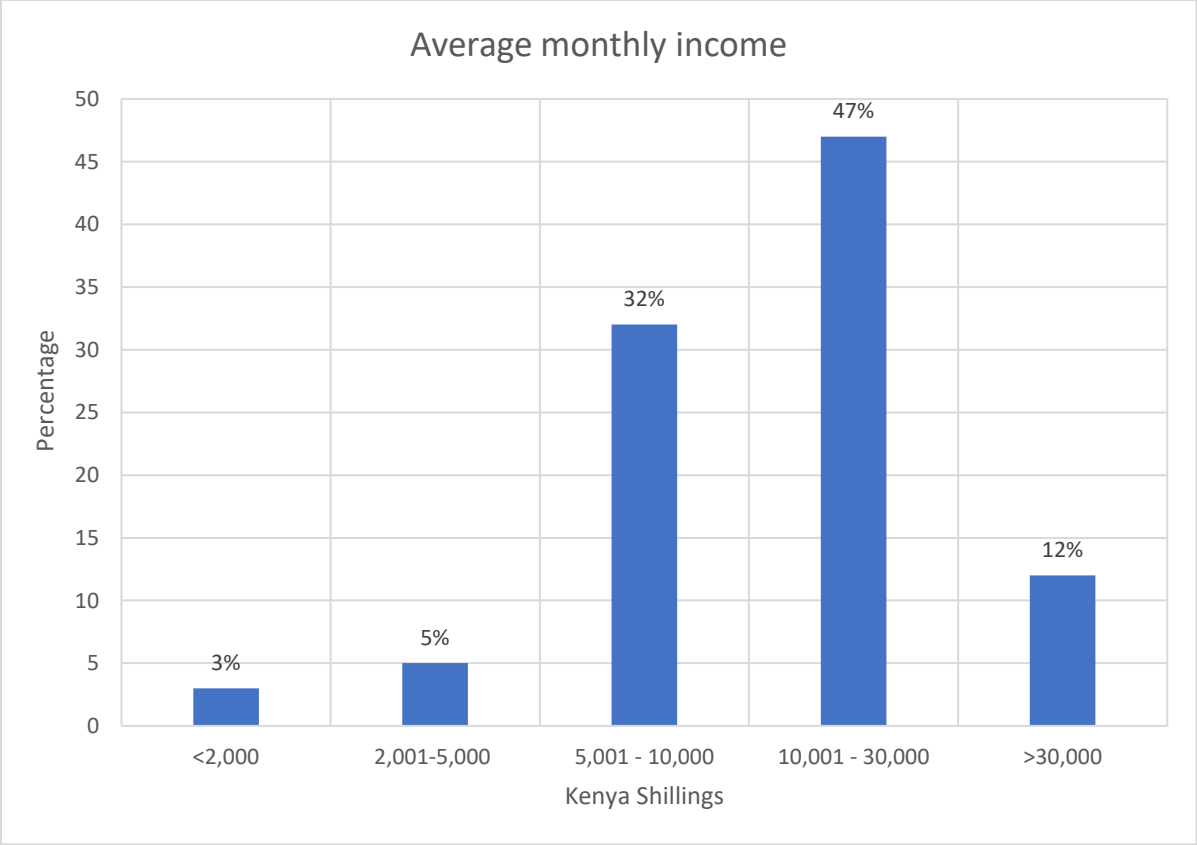


Figure 23: Average monthly income (Source: Field data 2017)

4.3.7 Source of water for agricultural use

The source of water being used on the farms is an important indicator of the use of water resources in the study area. For most of the farmers, 76% of respondents, the water used for irrigation on farms is abstracted from rivers and streams that drain from the base of the Nyambene Hills and flows into the park. Some farmers have obtained water abstraction permits from WRMA while some farmers illegally abstract water without the required permits. There is also a challenge of over-abstraction of water since there is inadequate monitoring by WRMA officials, a situation that has been fuelled by inadequate financial and human resources to carry out frequent checks in the community.

Some of the farmers have adopted unconventional methods of water abstraction where they line sand bags to divert water flow to their farms, a situation that has led to inadequate water for user downstream including the park itself. This increased irrigation has resulted in lower water volumes and in some cases no water flowing into the park. As a result, wildlife in the park move up stream in search of water and green fodder to satisfy their needs.

Majority of the respondents, 37%, use water obtained from rivers that are located upstream of the park for agricultural use. 27% of the respondents use water from boreholes that have been sunk in the study area. 19% of the respondents use water from springs and well for agricultural use during the rainy season. A few of the respondents, 15%, use water that is obtained from rivers and streams that are located downstream of the park. A small portion of the respondents, 2%, use water that is obtained from water vendors who get the water from different parts and bring it to surroundings in the study area.

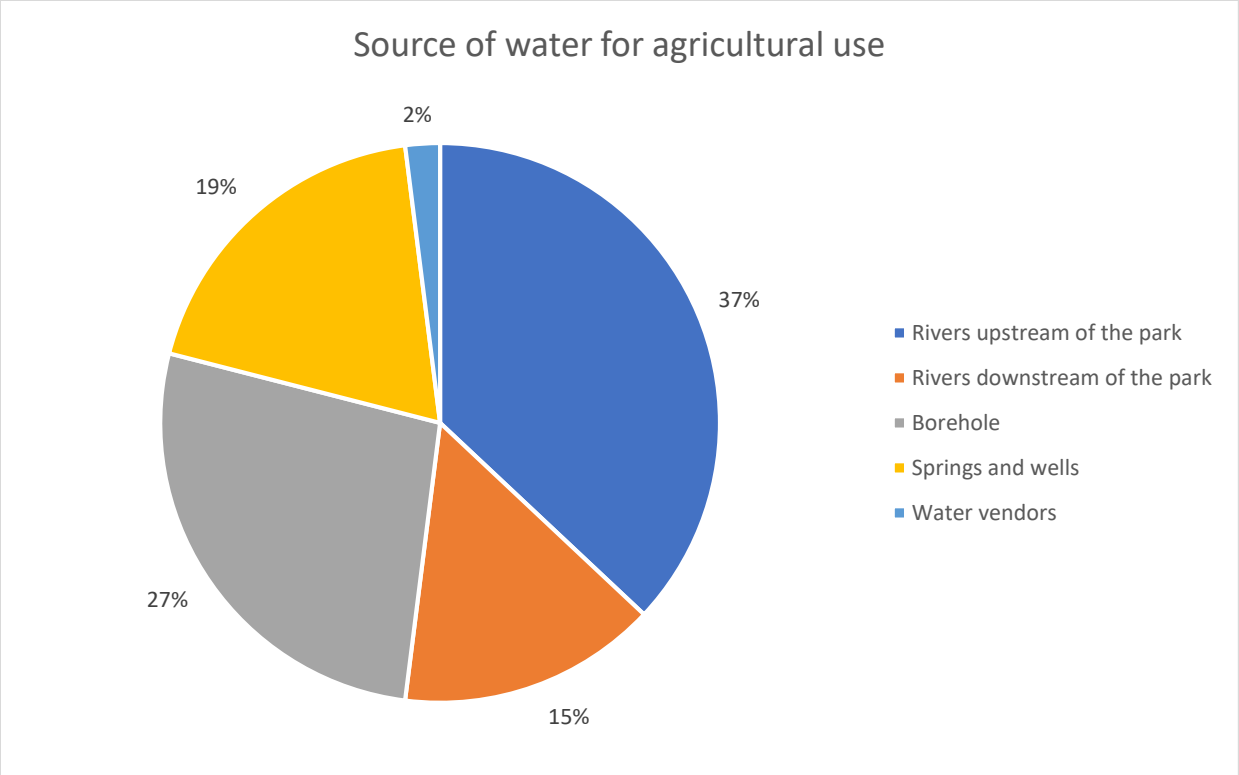


Figure 24: Source of water for agricultural use (Source: Field data 2017)

4.3.8 Land ownership

Land ownership directly relates to anticipated land fragmentation patterns in the study area. This is because of the widely practiced tradition of land inheritance of a farmer's dependants. Farmers who have bought land and settled in the study area are using improved farming methods as opposed to traditional farming methods that are used by natives of the study area. The improved farming methods include irrigation farming and farming in green houses. Land owners who have rented farms for farming purposes use intense farming methods to ensure maximum output from their farms. Some of the farming methods used include inter-cropping and mixed farming.

Majority of the respondents, 43%, are ancestral land owners of the land that they use for agricultural activities. Part of the respondents, 33%, are land owners who have bought land in the study area from various parts of the country. A small proportion of the sample population, 24%, have rented the land that they use for agricultural activities.

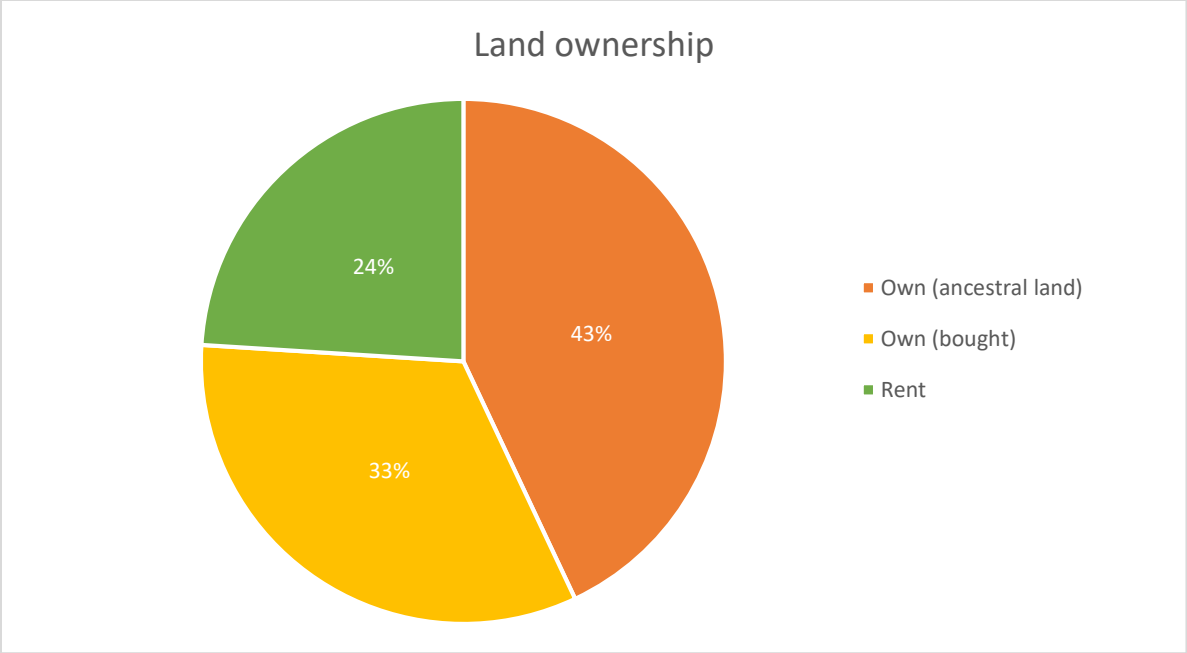


Figure 25: Land ownership (Source: Field data 2017)

4.3.9 Crops cultivated on farms

The type of crop cultivated has a direct correlation to irrigation water needs and farm input needs i.e. fertiliser and pesticides. The type of crops planted in the area consist of maize, bananas, Khat (miraa), green grams, tomatoes, watermelon, mangoes and cow peas. Crops under irrigation include Khat (miraa), tomatoes, green grams and mangoes. Maize is generally grown under rain-fed agriculture. The green house concept is continually gaining popularity in the area with farmers focussing on horticultural crops such as capsicum, tomatoes, chillies and strawberries.

Majority of the population, 43%, cultivate Khat (miraa) on their farms as a cash crop. 22% of the respondents cultivate water melon as a horticultural crop that is sometimes inter-cropped with other horticultural crops. A small proportion, 21%, engages in banana cultivation which is the traditional crop cultivated in the study area. Other horticultural crops, majorly capsicum, is also cultivated in the study area with 13% of the respondents engaging in this crop cultivation. A small proportion of the respondents, 7%, are planting maize on their farms. 3% of the respondents cultivate other crops which include beans, potatoes, and onions.

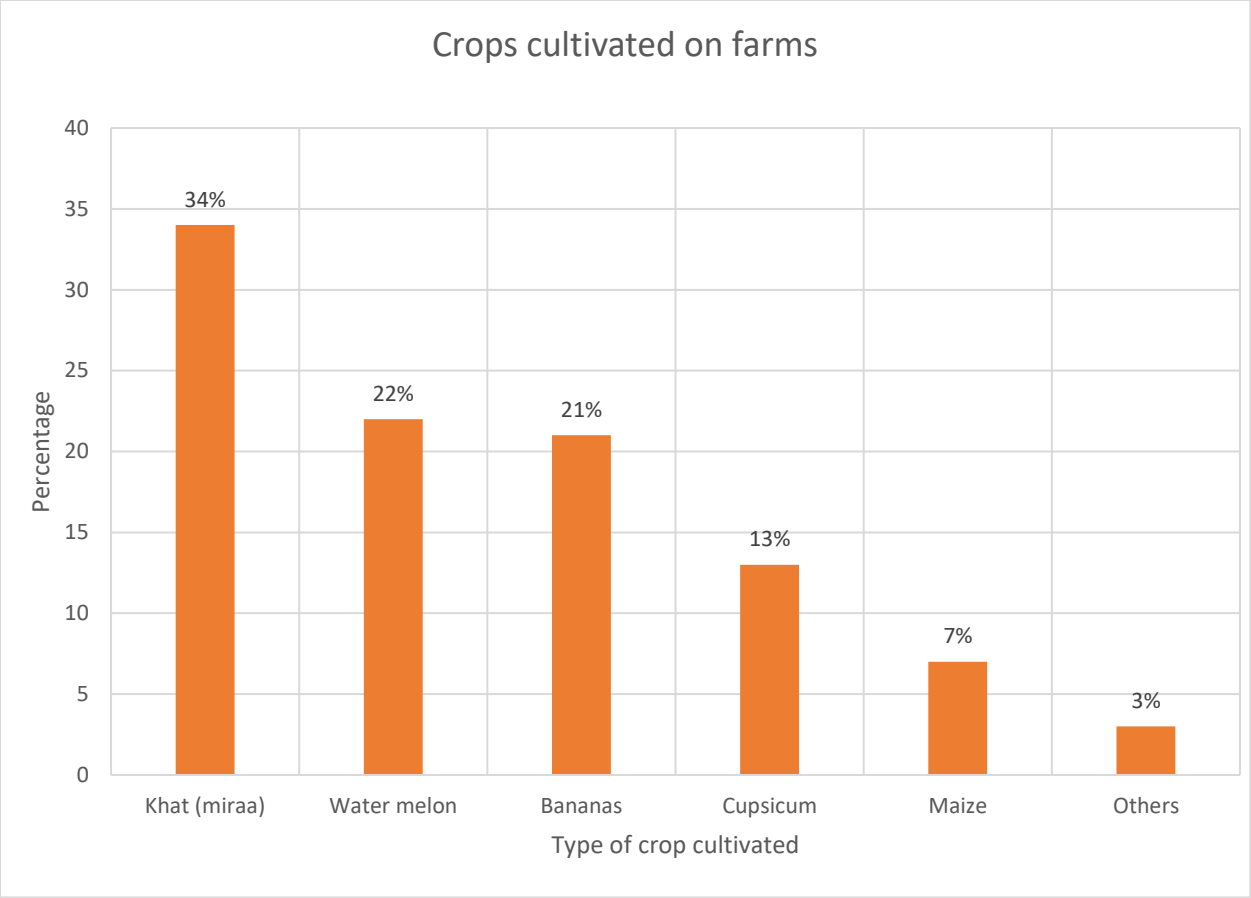


Figure 26: Crops cultivated on farms (Source: Field data 2017)

4.3.10 Duration of farming on land

Majority of the respondents, 57%, have been cultivating on their lands for more than five years. This represents respondents who own ancestral land, those who have bought land as well as those who have rented land for agricultural purposes. Farmers who have been cultivating their land for 3 to 5 years represent 21% of the respondents in the study area. Only 4% of the respondents have been cultivating their land for less than a year. This statistic represents farmers who have recently moved to the study area to practice agriculture.

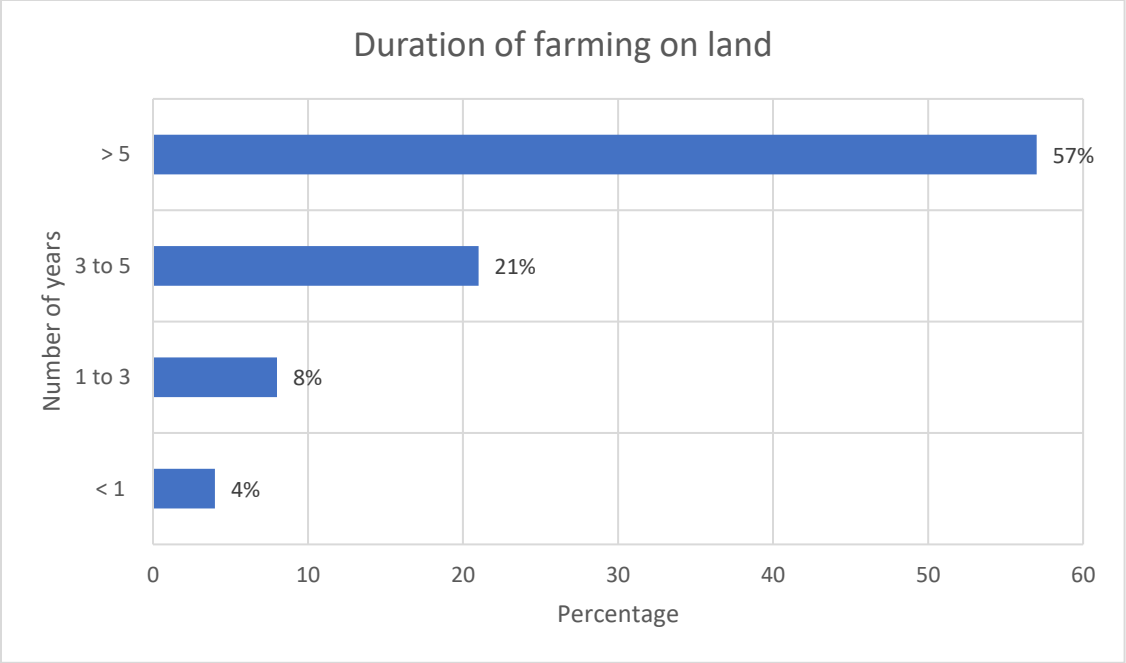


Figure 27: Duration of farming on land (Source: Field data 2017)

4.3.11 Size of farms

Data on farm size was important in determining the extent of agricultural activity in the study area. This was obtained from information in the household questionnaires as well as general observation of the farms while traversing the study area. For this study, small scale farms are those less than 1 ha, medium scale is more than 1 ha and less than 5 ha and large scale is more than 5 ha. The common size of land size is medium scale which represents 48% of the respondents. 34% of the respondents own small scale farms while a small portion, 18%, own large-scale farms. Statistics from Meru County's CIDP (2013-2017) also indicate that the average farm size in the study area ranges from 1.8 ha for small-scale farmers to 18.25 ha for the large-scale farmers.

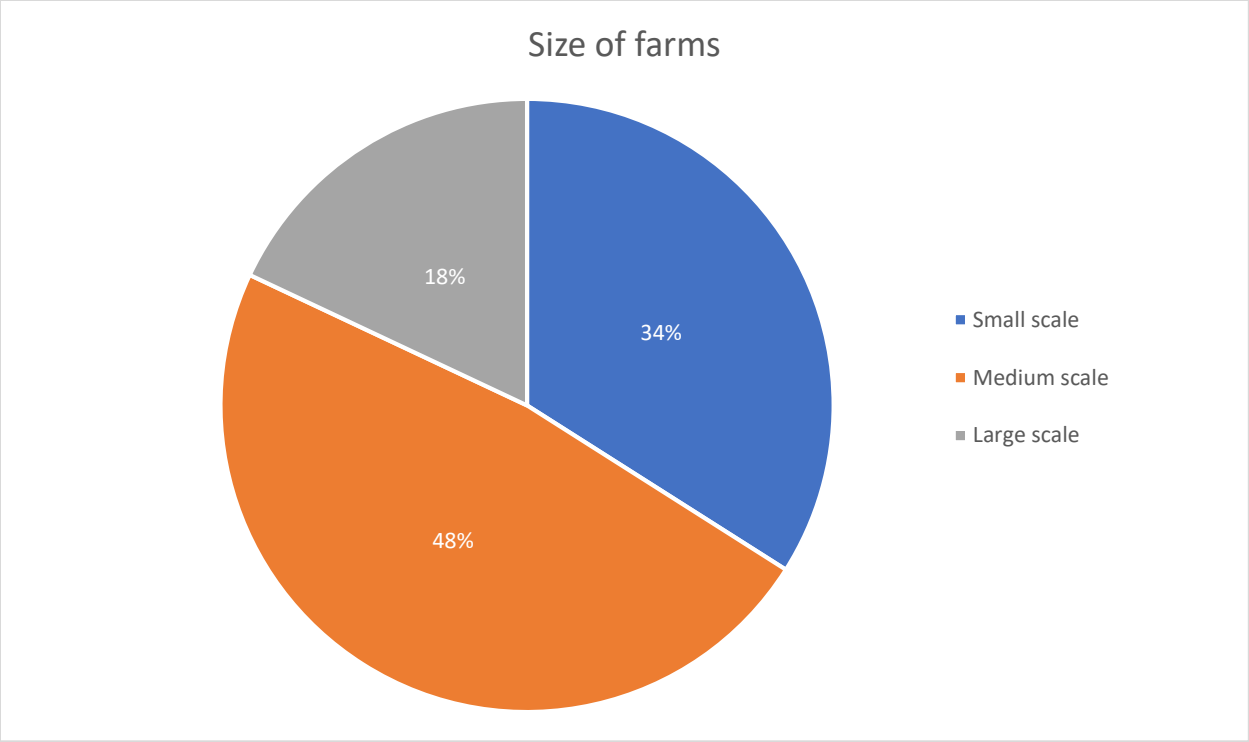


Figure 28: Size of farms (Source: Field data 2017)

4.4 Impacts of agricultural developments on biodiversity conservation

4.4.1 Human wildlife conflicts

The number of reported human wildlife conflicts associated with agricultural farming has been increasing over the years in the study area. This is evident from the statistics indicated in the table below where the total number of HWC incidences in the study area in 2014, 2015 and 2016 are 367, 526, and 540 respectively. The crop types that were most affected are maize and bananas and the wildlife that was involved in these interruptions were baboons, elephant, buffalo, monkey for maize and baboons, monkey, elephant, buffalo for bananas. The HWC incidences associated with maize and banana farming has been increasing since 2014 an indication that there has been an expansion in farming maize and bananas hence the high frequency of wildlife disruptions. HWC related to maize farming increased from 103 to 144 to 186 in 2014, 2015 and 2016 respectively. HWC related to banana farming increased from 83 to 108 to 132 in 2014, 2015 and 2016 respectively. Table 3 gives a summary of the number of reported HWC incidences in MNP buffer zone.

Table 3: HWC incidences in 2014, 2015 and 2016

Period	Crop/Animal Affected	Wildlife Involved	No. of Incidences
01/2014 – 12/2014	Maize	Baboons, elephant, buffalo, monkey	103
	Mangoes	Baboons, elephant, buffalo	12
	People	Elephant, buffalo, lion, snake, leopard, crocodile, hippo	45
	Fence/post/wire	Elephant, buffalo, baboons, giraffe	50
	Goats	Hyena, leopard, crocodile, cheetah	13
	Sheep	Leopard, hyena	4
	Tomatoes	Baboons, elephant	17
	Cow	Hyena	4
	Bananas	Baboon, monkey, elephant, buffalo	83
	Green grams	Baboons, hippo,	36
	Sub-total HWC Incidences		**367**
01/2015 – 12/2015	Cowpeas	Baboons, elephants	34
	Goats	Hyena, leopard, crocodile, cheetah	20
	People	Elephant, buffalo, lion, snake, leopard, crocodile, hippo,	24
	Maize	Baboons, elephant, buffalo, monkey	144
	Green grams	Baboons, hippo,	47
	Tomatoes	Baboons, elephant	26
	Cow	Hyena, leopard	4
	Fence/post/wire	Elephant, buffalo	72
	Bananas	Baboon, monkey, elephant, buffalo	108
	Sheep	Leopard, hyena	5
	Mangoes	Baboons, elephant, buffalo	42
	Sub-total HWC Incidences		**526**
01/2016 – 12/2016	Maize	Baboons, elephant, buffalo, hippo	186
	Green grams	Baboons, hippo,	70
	People	Elephant, buffalo, lion, snake, leopard, hippo	54

Period	Crop/Animal Affected	Wildlife Involved	No. of Incidences
	Bananas	Baboon, monkey, elephant, buffalo	132
	Fence/post/wire	Elephant, buffalo	18
	Goat	Hyena, leopard, crocodile, cheetah	35
	Cow	Hyena, leopard	6
	Sheep	Leopard, hyena	7
	Mangoes	Baboons, elephant, buffalo	32
	Sub-total HWC Incidences		**540**

4.4.2 Community agricultural practices that affect biodiversity conservation

Agricultural activities which include both farming and pastoralism have encroached the study area. In the north-western part of the park, farming is now adjacent to the park's electric fence. The community living adjacent to the park revealed that there are benefits of leaving next to the park for various reasons. These include the availability of water from streams and rivers that flow into the park that they use for irrigation on the farms and herding their livestock in the park's buffer zone during dry seasons.

Other respondents indicated that they were drawn by the infrastructure (roads) that has been constructed with the aim of making the park accessible, this has enabled the farmers to transport their produce from the farms easily to market centres. Some respondents indicated that they have been involved in community conservation practices in collaboration with the park and this had directly and indirectly created income for them and other members in their households, specifically women and youth.

Pastoralists indicated that they have been trying to engage the park management to let them graze their animals in the park's buffer zones during drought periods, this is still under discussion with the park management.

Plate 1 shows unconventional water retention methods used by farmers in the study area to obtain water for agricultural use. This is a growing trend in the park's north-western fronts.

Plate 1: Unconventional water retention methods used by farmers in the study area (Source: Author 2017)

Over abstraction of water from upstream rivers and streams entering the park has resulted in reduced water for wildlife in the park. WRMA and NEMA officers revealed to us that the water abstraction permits issued to farmers vary depending on each farmer's needs and water availability from the source. WRMA charge KES 50 cents for every cubic meter of water abstracted within the permit allocation, and KES. 1 shilling as a penalty for water abstracted above the permit allocation. From the average household income of the respondents, the above charges are affordable by more than 50% of the respondents. This has led to more household obtaining permits for water abstraction for agricultural use.

Additionally, WRMA and NEMA officers indicated that there is a challenge of monitoring the water abstraction regimes against the issued permits. They indicated that they do not have enough financial and human resources to constantly be checking on the farmers' water abstraction. This situation has led to over-abstraction of water from the streams flowing into the park. KWS water gauging stations have recorded continued reductions in water levels throughout the year, an indication that water entering the park has significantly reduced. This has an implication on water availability for wildlife in the park. In the reduction of water or lack of water in the park, wildlife is drawn to move up stream in search of water and green fodder during dry spells. This search for water and green fodder has resulted in interactions with farmers that has often degenerated to HWC.

WRMA guidelines also indicate that no farming activity should be conducted in riparian areas i.e. 30 metres from a river or stream. However, farmers have planted their crops in the riparian areas. This has resulted in some farmers being charged for penalties and loss of crops in some cases where the crops were cleared by the relevant authorities.

Plate 2 illustrates equipment used to abstract water from streams and the intense irrigation methods being used;

Plate 2: Over abstraction of water from rivers for agricultural use and irrigation methods used (Source: Author 2017)

The above listed practices if not well regulated and monitored have the potential to cause detrimental effects on biodiversity conservation. Over abstraction of water resources up stream of the park has led to drying up of streams and rivers that provide water to the park. This has resulted in alteration of the natural habitat for wild animals in the park. The animals in the park have to travel longer distances to get drinking water and pasture since pastoralists let their animals graze in the park sometimes there by depleting natural resources for the wild animals in the park.

Plate 3: Reducing water levels in rivers and streams entering MNP
(Source: Author 2017)

The study area has a significant livestock population which comprises sheep and goats. Camels, donkeys and cattle are also present but in lower populations. The actual numbers of the different types of livestock are determined by season with the highest numbers of livestock in areas adjacent to the park being in the dry season. The number of livestock decreases in wet seasons as the pastoralists move to other parts of MCA.

A small population of sheep, cattle, goats, camels and donkeys have been recorded in the northern part of MNP. Significant livestock incursions are mainly concentrated in Bisanadi national reserve which is adjacent to MNP. Figure 29 shows the distribution of livestock in MNP and its environs.

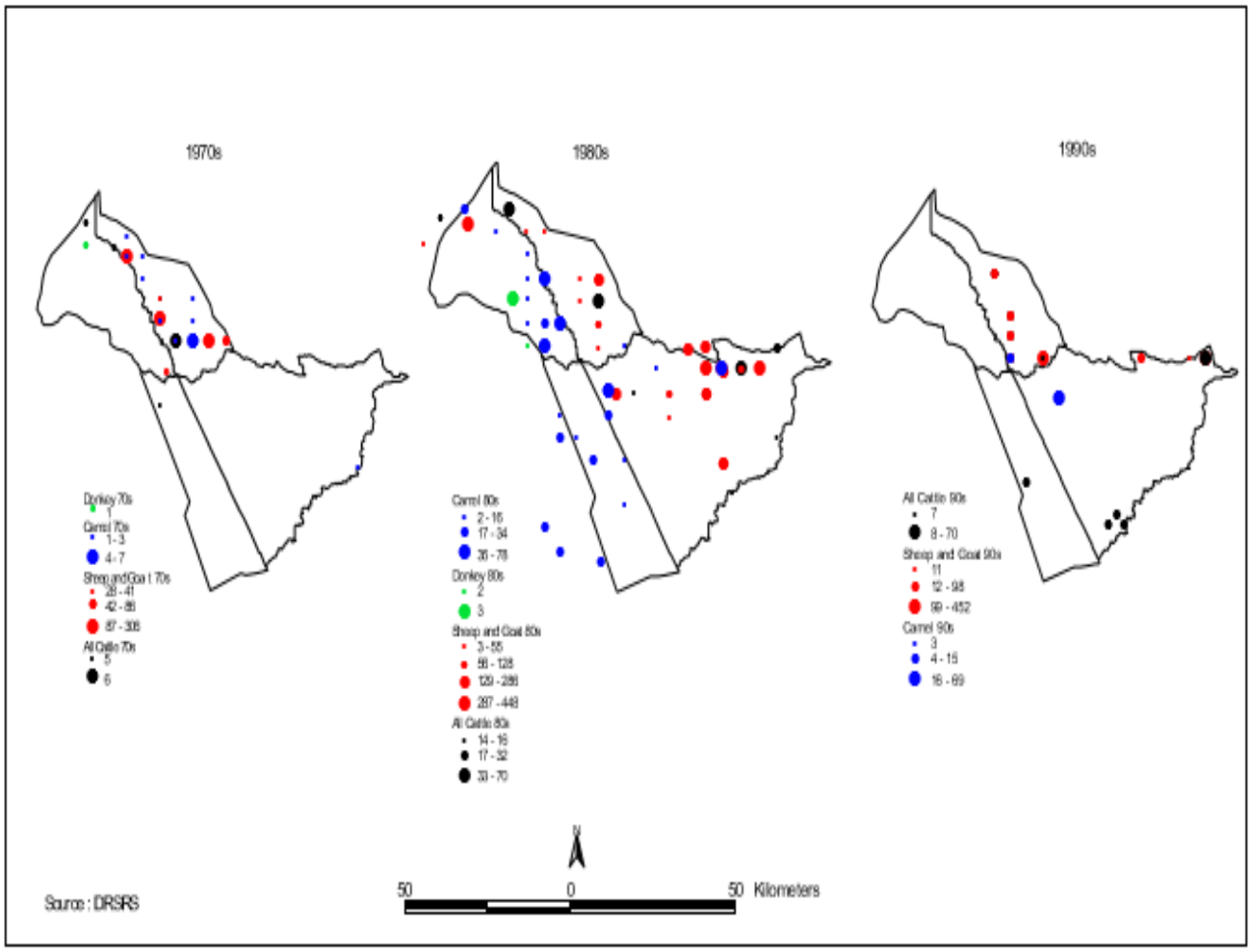


Figure 29: Livestock distribution in MNP and its environs (Source: DRSRS)

CHAPTER FIVE

SUMMARY OF THE FINDINGS, CONCLUSION AND RECOMMENDATION

5.0 Chapter overview

This section summarises the study findings informed by the objectives of the study. It also presents conclusions of the study as discussed in the chapters above. Lastly, this section presents recommendations that are aimed at ensuring sustainable biodiversity conservation in the wake of an ever-expanding agricultural sector in buffer zones of conservation areas.

5.1 Summary of the findings

The study findings are aligned to the aim of the study which was to document land fragmentation and subdivision trends and changing crop types in MNP's buffer zones, determine the impacts of land use changes on community-based conservation; and the size and extent of human-wildlife conflicts in MNP's buffer zones.

5.1.1 Land fragmentation and subdivision trends and changing crop types in MNP's buffer zones

Land ownership directly relates to anticipated land fragmentation patterns in the study area. This is because of the widely practiced tradition of land inheritance of a farmer's dependants Observations were made of such land fragmentations between family members. This has also allowed natives of the study area to sell land to migrants into the area who have intensely focussed on irrigation farming. This is also evident from the reducing size of average farm size. The elderly people in the community indicated that they used to own large tracts of land between 20-35 ha. The situation on the ground now is that majority of the land owners have medium scale farms that range between more than 1 ha and less than 5 ha. Indications from farmers of their future farm developments indicate that average land size per household is expected to continue decreasing in future. Spatial analysis indicates that the area under rain-fed shrub vegetation reduced significantly

by 66.69 km^2 between 2000 and 2016. This is majorly attributed to clearing of shrub vegetation to covert these areas into farmland.

There is a distinct change in the crop types in the study over the years. Maize is the dominant traditional crop in the study area largely because it cultivated under rain fed agriculture. Some farmers have also planted bananas for over 20 years also under rain fed agriculture. The most recent crop types beginning 2000 include Khat (miraa), green grams, tomatoes, watermelon, mangoes and cow peas. Crops under irrigation include Khat (miraa), tomatoes, green grams and mangoes. Since 2000, there has been an increase in use of farm inputs such as fertiliser and pesticides to improve produce quantities during harvesting. Irrigation farming has also increased in popularity because it allows the farmers to farm throughout the year which results in increased produce majorly for horticultural crops. However, unconventional methods of water abstraction are being used to acquire water from the streams in the study area for irrigation. This includes the lining of sand bags to divert water flow into the farms, a situation that has resulted in reduced water volumes downstream. The green house concept is continually gaining popularity in the area which has enabled the cultivation of crops such as capsicum, tomatoes, chillies and strawberries.

5.1.2 Impacts of land use changes on community-based conservation

There is a direct negative impact on community-based conservation because of the land use changes that have occurred in the study area. Most of the respondents indicated that there are no direct benefits of being involved in community-based conservation which they indicated required a lot of their time and in some instances at night (for the case of policing against poachers). The respondents indicated that many people are now engaging in agricultural activity after witnessing the financial returns that other farmers were getting. The increase in agricultural activity in the park's buffer zone has resulted in increased vulnerability and exposure to incidences with wildlife that has in most cases resulted in HWC, this has made some of the community members to have a negative attitude towards biodiversity conservation. They argue that they are protecting wildlife that in turn ruins their crops and in extreme instances results in loss of life of community members.

5.1.3 Size and extent of human wildlife conflicts in MNP's buffer zones

There is an increase in the size and extent of HWC in the study area. This is evident from the ever-increasing number of reported HWC incidents that are associated with agricultural activity in the park's buffer zone. The total annual number of HWC incidences in the study area in 2014, 2015 and 2016 were 367, 526, and 540 respectively. These conflicts affected maize and bananas farmers the most with baboons, elephants, buffaloes and monkeys being involved in the conflicts frequently. The HWC incidences associated with maize and banana farming has been increasing since 2014 an indication that there has been an expansion in farming maize and bananas hence the high frequency of wildlife disruptions. HWC related to maize farming increased from 103 to 144 to 186 in 2014, 2015 and 2016 respectively. HWC related to banana farming increased from 83 to 108 to 132 in 2014, 2015 and 2016 respectively. The farmers are farming closer to the park and this has resulted in an increase in vulnerability to HWC since they are moving closer to the park's fence.

5.2 Conclusion

After assessing the impacts of agricultural developments on biodiversity conservation in MNP's buffer zone, it is clear that agricultural activity is going to continue increasing in the study area. The 2009 human population census projections also indicate an increase in human population in the study area which will also result in increased agricultural activity in MNP's buffer zone. If the current unconventional agricultural practices are not adequately addressed, this may result in species degeneration, species extinction in extreme cases and conversion of wildlife habitats.

Despite the negative impacts on biodiversity conservation as a result of uncontrolled agricultural development in the study area, it was established that agricultural development is necessary in bringing a balance to the community's social and economic needs. The ecosystem management concept should be integrated with the sustainable biodiversity conservation model to ensure a cohesive approach to managing the different and often competing needs of biodiversity conservation and agricultural development.

5.3 Recommendations based on study findings

Based on the findings of impacts of agricultural developments in the study area on biodiversity conservation, the following recommendations are made to address that identified challenges. The recommendations will take a phased approach in implementation. Short-term recommendations should be implemented immediately and up to a period of 5 years. Long-term recommendations should be implemented over a longer period i.e. 5 – 10 years.

5.3.1 Short-term recommendations

1. Promotion of coordinated efforts in biodiversity conservation for implementing government entities i.e. KWS, KFS, WRMA, NEMA and Ministry of Agriculture, Livestock and Fisheries.
2. Awareness creation for community members on importance of biodiversity conservation
3. Promotion of sustainable agricultural practices that do not negatively impact on biodiversity conservation
4. Promotion of innovative community-based conservation initiatives
5. Increased community participation in decision making for matters relating to community-based conservation
6. Revision of the Payment for Ecosystem Services (PES) scheme to increase community participation in community-based conservation.
7. Increase penalties for law offenders e.g. poachers to reduce anti-conservation practices
8. Improve MNP's framework for resolving HWC in the study area

5.3.2 Long-term recommendations

1. Development of a Sustainable Biodiversity Conservation Strategy that takes into consideration social, economic and environmental needs of the community in MNP's buffer zone
2. Policy revision to include the community land under the MNP's jurisdiction

3. Water abstraction permits should be revoked by WRMA and NEMA for farmers who do not adhere to the allocated water abstraction limits
4. Increase in financial and human resources for WRMA and NEMA water abstraction monitoring officers

5.4 Areas for further research

1. Identification of the impacts of use of farm inputs such as fertilizers and pesticides on water quality for water entering the park and the resultant impact on wildlife conservation.
2. Identification of changes in wildlife migratory routes because the traditional wildlife migratory routes have been blocked by farms.
3. Determination of changes in water base flow volumes in park because of the increased agricultural irrigation upstream.

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APPENDICES

APPENDIX I: Work Plan

Activity	Nov 2015	Dec 2015	Jan 2016	Feb 2016	Mar 2016	Apr 2016	May 2016	Jun 2016	Jul 2016
1. Problem identification - Literature review and analysis									
2. Concept note drafting and presentation									
3. Proposal drafting and presentation									
4. Preparation of data collection material									
5. Data collection, administration of questionnaires (field work)									
6. Data processing – data entry & analysis									
7. Research proposal report drafting & presentation									

APPENDIX II: Budget

Item	Unit cost (KES)	Quantity	Amount (KES)
1. Printing questionnaires	40 KES	100 Copies	4,000
2. Enumerators	3,000 KES	3 Enumerators	9,000
3. Local transport	6,000 KES	3 Days	18,000
4. Stationery	5,000 KES	5 Pieces	25,000
5. Printing report	1,000 KES	3 Copies	3,000
6. Binding report	1,000 KES	3 Copies	3,000
7. ICT (internet, phone)	1,000 KES	8 Months	8,000
8. Procuring data from data banks	2,000 KES	3 Data sets	6,000
TOTAL			**76,000**

APPENDIX III: Key Respondent Interview Guide

DYNAMICS OF AGRICULTURAL DEVELOPMENT IMPACTING ON BIODIVERSITY CONSERVATION IN MERU NATIONAL PARK, KENYA

KEY INFORMANT INTERVIEW GUIDE

PART 1: GENERAL INFORMATION		
Name of Enumerator:	Questionnaire No:	Date:
	County:	Ward: Town:
Type of institution: (park/conservancy/county Govt, private sector)		

PART 2: ORGANISATION DETAILS	
1. Name of institution:	
2. Name of respondent:	
3. Contact details of respondent:	
4. Number of beneficiaries:	

PART 3: BIODIVERSITY CONSERVATION	
1. What is the importance of biodiversity conservation in this region?	
2. What are the socio-economic benefits of being adjacent to MNP?	
3. What are the negative impacts of agricultural development on biodiversity conservation?	
4. What can be done by KWS to improve biodiversity conservation?	
5. What can be done by the community to improve biodiversity conservation?	
6. What can be done by the private sector to improve biodiversity conservation?	
What can be done by the County Govt to improve biodiversity conservation?	
7. What initiatives are being implemented by your organisation to ensure sustainable biodiversity conservation?	
8. List all stakeholders that should be involved in biodiversity conservation in this region.	
9. What new and innovative initiatives of biodiversity conservation should be adopted?	

APPENDIX IV: Household Questionnaire

DYNAMICS OF AGRICULTURAL DEVELOPMENT IMPACTING ON BIODIVERSITY CONSERVATION IN MERU NATIONAL PARK, KENYA HOUSEHOLD QUESTIONNAIRE	
Enumerator Name:	Questionnaire no.:
Date:	Coordinates:

SECTION A: GENERAL INFORMATION	
Name of respondent:	
Gender: ☐ Male	☐ Female
Highest level of education ☐ Degree ☐ Diploma ☐ Secondary ☐ Primary	
Age	
Town:	County: Ward:

SECTION B: SOCIO-ECONOMIC ACTIVITIES

1. List out the five most common livelihoods in your area e.g. irrigated agriculture, hunters, fuelwood gatherers, fishermen, Khat (miraa) farmers, etc.).

2. What is your main source of income?
   ☐ Farming ☐ Trade ☐ Formal employment ☐ Others (specify)

3. What is your average monthly income?
   ☐ <2000 ☐ 2000-5000 ☐ 5000-10000 ☐ 10000-30000 ☐ >30000

4. What are the sources of water for household use?
   ☐ Rivers Upstream of the park ☐ Rivers Downstream of the park ☐ Springs and wells in the parks ☐ Boreholes ☐ Water vendors

5. What are the sources of water for agricultural use?
   ☐ Rivers Upstream of the park ☐ Rivers Downstream of the park ☐ Springs and wells in the parks ☐ Boreholes ☐ Water vendors

6. Do you own or rent the farm?
   ☐ Rent ☐ Own ☐ Others (specify)

7. What types of crops do you cultivate on your farm?

8. How long have you been cultivating the above listed crops (specify exact duration)?
   ☐ > 1 year ☐ <1 – 3 years ☐ <3 – 5 years ☐ <5 years

9. What is the size of farms in this region?
   ☐ Small scale ☐ Medium scale ☐ Large scale

SECTION C: WATER AND LAND MANAGEMENT

10. What is the source of water used on the farm?

Source	Main	Alternate	Explain location of water source e.g. upstream, downstream, in the park etc.
River/stream	☐	☐	
Lake	☐	☐	
Municipal water	☐	☐	
Borehole	☐	☐	
Dam	☐	☐	
Others (specify)	☐	☐	

11. What fertilizer(s) do you use on your farm?
☐ Organic fertilizer (why?) ☐ Inorganic fertilizer (why?)

12. What water saving technologies do you use on the farm?
☐ Irrigation ☐ Greenhouse ☐Others (specify)

13. What plans do you have for your farm?
☐ Expand farm size ☐Improve farm techniques ☐ Increase farm workers
☐ Others (specify)

14. What challenges do you encounter in farming in this area?
☐ Water ☐ Land ☐ Markets (local/ international)
☐ Local authorities ☐ Operational costs ☐Taxes, levies, policies

SECTION D: BIODIVERSITY & ENVIRONMENT

1. What are the benefits of leaving adjacent to the park?
☐Source of fuel wood ☐ Source of water ☐ Employment ☐ Grazing animals
☐Scenic beauty ☐ Security ☐ Others (specify)

2. What is the frequency of human-wildlife conflicts?
☐ Weekly ☐ Once a month ☐ Once in six months ☐ Once in a year
☐ Others (specify)

3. What is the cause of human-wildlife conflicts in this region?

4. What interventions should be put in place to address human wildlife conflicts?

5. Why is biodiversity conservation important?

6. What biodiversity conservation practices are you involved in?

7. (a) Is the parks' involvement of the community in conservation initiatives effective?

(b) What can be done to improve this?

SECTION E: GENERAL COMMENTS

Additional comments from respondent (General comments, suggestions and concerns about sustainable biodiversity conservation without hampering agricultural development)
Comments from enumerator