SETTLEMENT SCHEMES AND THEIR IMPLICATION ON EASTERN MAU WATERSHED, NAKURU COUNTY, KENYA

FREDAH CHEROTICH

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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.

Signature…… Date…….

Fredah Cherotich

N50/27738/2018

I confirm that the work reported in this project was carried out by the candidate under my supervision.

Signature: …… Date: …….

Dr Sammy Letema
Department of Spatial and Environmental Planning, Kenyatta University

DEDICATION

This project is dedicated to my late mum, Jeniffer Mutai for her encouragement to pursue education to the highest level. To my grandmother, Mrs Rachel Korir and father Mr. Richard Mutai for their support and my siblings, Kelvin, Lynn and Enock for their inspiration.

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ABSTRACT

Settlement schemes are aimed at settling landless people and those displaced by disasters to support socio-economic and environmental development of a country. Eastern Mau Forest Reserve is an important watershed that has settlement schemes established, which has led to encroachments and degradation of the watershed. This study, therefore, assessed the implications of human settlements on Eastern Mau watershed by examining the trends in land use/cover change, settlement schemes and river flows for four decades, from 1979 to 2020. Eastern Mau Forest Reserve is a major water tower therefore the large tracts of land that have been cleared coupled with the settlements in it is a worrying trend. It is essential to develop an approach that will aid in assessing land use land cover changes and effects on hydrological components at catchment level to aid in planning, use and management of resources. Primary data was collected from key informant interviews based on purposive sampling. Secondary data was derived from Landsat satellite images over a 10-year period and analysed using Maximum Likelihood Function from ArcGIS. Data on river flows from River Njoro was obtained from Water Resources Authority Office in Nakuru County for 1979-2020. Rainfall data for 1979-2020 was obtained from Kenya Meteorological Station, Nakuru Town. Time series analysis is used to understand the trend in river flows over time while Pearson correlation is used to determine relationship between farmlands and river flows. The results indicate a sharp decline in forest cover by 42.7% and an increase in farmlands by 41%. Dense vegetation and farmlands have an inverse relationship as an increase in farmlands lead to a decrease in forest cover and vice versa. People have settled beyond the established settlement schemes leading to encroachment and drying up of some rivers. There is also an increase in rainfall and river flows over the years, with monthly river flows increasing in peak flows and declining during low seasons. There is a positive correlation between farmlands and river flows between 1989 and 2020. Settlements affect land cover that in turn affects forests and impacts capacity of land to absorb rainfall water, which leads to higher runoff and subsequently higher flows. There is need for regeneration of encroached areas and defining boundary of Eastern Mau to allow initiatives and interventions that help with sustainable management of the watershed area.

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ACRONYMS AND ABBREVIATIONS

CIDP	County Integrated Development Plan
FAO	Food and Agriculture Organization
GIS	Geographic Information Systems
KANU	Kenya African National Union
KFS	Kenya Forest Service
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
KWTA	Kenya Water Towers Agency
LULC	Land use land cover
NEMA	National Environmental Management Authority
RoK	Republic of Kenya
UNECE	United Nations European Commission for Environment
UNEP	United Nations Environmental Program
UNESCO	United Nations Education, Scientific and Cultural Organization
WRA	Water Resources Authority

DEFINITION OF TERMS

Watershed management plan: A strategy and work plan for identification of problems and threats to water resources that provides for assessment and management by various stakeholders (Heathcote, 2009).

Integrated Watershed management: The process of managing natural resources within a watershed and related human activities while addressing the challenges which could affect it ((Heathcote, 2009)

Wetland: An area of land covered with surface or ground water (William & James, 2015).

Catchment: An area of land in which water flows into a river, lake or reservoir (Pande, 2020).

Land use practices: The approaches used in modification of natural environment for certain purposes (Rattan, 2019).

Forest reserve: An area of forest that is set aside by the government for preservation of biodiversity by restricting human activities ((Newson, 2012)

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Settlement schemes are areas set aside by the government with an aim to support socio-economic development of a region (Fuseini & Kemp, 2015). It is an intervention to promote the utilization of land resources for provision of basic needs and enhanced development by promoting land ownership as the basis for security and decent livelihoods. The schemes are often allocated to landless people who are have been displaced by natural disasters or man-made activities such as conflicts (Carneiro, 2017). The creation of settlement schemes helps reduce population pressure in over populated areas, increases agricultural production, creates employment, demarcates large parcels of land into smaller economic viable units and enhances provision of infrastructure (Coale & Hoover, 2015).

Watershed management faces several challenges including encroachment as people have been given land rights in fragile ecosystems such as forested areas and wetlands, which impacts on water bodies (Boone, 2012). Catchment control and catchment planning is faced with the problem of land use and management which leads to deforestation and disruption of traditional land rights (Newson, 2012). The purpose of planning for watersheds is to protect the resources for future generations (Bertule *et al.*, 2018). Sustainable watershed management should not only be focused on protecting the resources but overall quality of life for enhanced development of future generations (Heathcote, 2009).

Settlement schemes in forested areas lead to destruction of watersheds and disrupt forest and watershed management efforts (Sauer, 2018) . As people clear forests to pave way for settlements, deforestation and land degradation sets in (Gills & Morgan, 2020). This further leads to soil erosion, destruction of animal and plant habitats and depletion of water resources. Land use and land cover changes further lead to sedimentation which alter the river flows, water quantity and quality (Masuma & Adullah, 2020). Settlement programs hinder efforts aimed at sustainable use of natural resources and planning of watersheds.

Forests are considered important catchments areas as a large part of the world's water originates from forested areas (Alvarez-Garreton, Lara, Boisier, & Galleguillos, 2019). They are also valued for their sustained output of high quality of water. In addition, they help regulate precipitation, flow of rivers, streams and evaporation. Clearing of forests affects the water cycle, leading to drier climates due to increased evaporation (Prieto, Le Vine, Kavetski, García, & Medina, 2019). Management of forests and watershed areas is therefore intertwined as destruction of forests subsequently affects watersheds. One of the greatest threats to forest and watershed management is settlements in forested areas (Franklin, Johnson, & Johnson, 2018).

Forests are important ecological systems as they provide ecosystems functions and services (Prăvălie, 2018). Despite their importance, the global forest area has decreased alarmingly over the last few decades with vast effects felt across various regions (Alamgir *et al.*, 2020). This has resulted in efforts towards management of forest land to improve continuous flow of forests products and services with minimal effects on physical and social environment while enhancing sustainable development (Gills & Morgan, 2020). These efforts include development of regulations, agreements, institutions and initiatives at international and national level aimed at management of forests (Jorge & Julio, 2012).

Forested areas are attractive to live in due to the numerous resources they provide. In several regions across the world, there is a conflict between forests and agriculture (Sauer, 2018). Despite the presence of regulations meant to protect forests, human beings have continuously settled and destroyed forests (Lopez & Jason, 2013). Settlements schemes have also been established in forested areas by authorities in a bid to settle landless people, reduce population in highly populated area, increase food production and settled people displaced by different disasters (Hermon, Iskarni, Oktorie, & Wilis, 2017). There is rampant encroachment of the forested areas which further leads to destruction of forests and watersheds (Carneiro, 2017).

Globally, catchment areas play an important role in the spatial organization of human settlements. There is a consistent pattern of preferential cluster among people towards the upstream areas. Typically, 40% flow lengths of watersheds in all continents are occupied by human settlements (Yu, Serena, & Alberto, 2018). The availability of natural resources greatly influences the spatial pattern of settlements. Human societies evolved around natural resources and as they transitioned through different forms of development, their effect on natural resources became rampant. The settlement of people around Minqin Basin in Northwest China altered the drainage patterns of rivers and intensified ecological problems in the basin (Yaowen, Qiang, & Chansheng, 2017). It also led to water scarcity and conflicts as demand for water increased. The Chechlo Reservoir Catchment in Poland has greatly been affected by human settlements. There is a difference in mineral composition of water as it flows from the source and as it passes through settled areas. This is attributed to land use land cover changes, intensive agriculture and urbanization (Tomas, Andrzej, & Agnieszka, 2019).

Attention to management of catchments in Africa is increasing as several countries have been declared water scarce including Tunisia, South Africa, Algeria and Morocco (Guermazi, Milano, & Reynard, 2019; Murphy & Sprague, 2019). This declaration is based on availability of 1000m^3 of renewable water per person per year. In Tunisia for instance, people have been moved away from critical catchment areas with valuable resources and biodiversity. UNEP reported an overall loss of 15% of wetland area and 84% loss of wetland in Medjerdah catchment in Tunisia (Besset, Anthony, & Bouchette, 2019). The rapid loss of critical catchments has led to eviction of people living within forest reserves and wetlands.

Watershed management in Kenya faces several challenges including land tenure and traditional rights which define the management and control of the watersheds. The environment-poverty nexus, population pressure, politics and poor enforcement of the laws contribute to the challenges of watershed management (Salah & Ward, 2008). The existence of Mau Forest complex, one of the largest forests in Eastern Africa is under threat from anthropogenic activities with 40% of the forest cover already depleted (Shazia, 2019). Activities by people in the Mau Forest Reserve began during the

colonial era and continued after independence, with settlement schemes established in the forest complex (Thomas, 2004).

The development of settlement schemes in Mau Forest has been a sequence of activities and plans over the years. These plans include the 1954 Swynnerton Plan, 1961 Yeoman and Peasant Schemes, 1964 the Million Acre-Settlement Scheme and Harambee settlement schemes between 1966 and 1970 (Leo, 2011). The Kenya African National Union (KANU) political party regime under President Moi gradually allocated and compensated people with land in the 1980s with Mau Forest greatly affected despite its importance as a watershed area that needs to be conserved (Boone, 2012).

There have been conventions and treaties among countries to ensure sustainable management of watershed (Mather, 2014). Food and Agriculture Organization (FAO) provides guidelines on watershed management through community-based watershed management approaches in planning, allocation of land, monitoring, mapping, zoning and inclusiveness (Bertule *et al.*, 2018). The United Nations Education Scientific and Cultural Organization (UNESCO) International Hydrological Programme runs from 2014-2021 in UNESCO member states with an aim of mobilizing international co-operation, strengthening implementation of policies and capacity development to enhance water resources management and governance (UNESCO, 2014). Countries are therefore required to have laws, regulations and guidelines meant to protect watersheds within a country and where resources are shared, the various countries should have governing regulations as well (FAO, 2017).

Management of catchments faces several challenges including encroachment as people have been given land rights in fragile ecosystems such as forested areas and wetlands, which impacts on water bodies (Boone, 2012). Catchment control and catchment planning is faced with the problem of land use and management which leads to deforestation and disruption of traditional land rights (Newson, 2012). The purpose of planning for watersheds is to protect the resources for future generations (Bertule *et al.*, 2018). Sustainable watershed management should not only be focused on protecting the

resources but overall quality of life for enhanced development of future generations (Heathcote, 2009).

Land cover change involves the alteration of land cover or conversion into a new type. Land use changes are a result of alteration in land cover over time (Liping, Yujun, & Saeed, 2018; Souza *et al.*, 2020). In forest areas, land use land cover changes stem from agricultural activities which expand into marginal areas over time, demand for wood, charcoal and construction materials and expansion of settlement activities. Alteration of land use land cover affects forest and water resources (Franklin *et al.*, 2018). An insight into the patterns, extent and characteristics of land use land cover changes is important in making decisions for management of resources (Gashaw, Tulu, Argaw, & Worqlul, 2018). The research seeks to provide an insight into the impacts of settlements on Eastern Mau watershed. The proposition of this study is that there is a relationship between settlement of people in watershed and diminishing flow of water in the rivers.

1.2 Problem Statement

The last three decades have seen the Mau Forest Complex undergone changes in land uses as a result of population pressure, the need for land to settle and carry out agricultural activities (KWTA, 2017). The establishment of settlement schemes in a forested area and further encroachment has led to deforestation of Mau (Shazia, 2019). The result of settling in Eastern Mau Forest Reserve is division of land and destruction of wetlands which may impact flow of rivers during the dry seasons (Kibuba & Jenkins, 2005). The land administration systems in Kenya have allowed previous regimes to establish settlement schemes and place infrastructure to serve people in the forested areas (Olang & Kundu, 2011).

There are international and national guidelines on development of settlement schemes in forested areas while enhancing environmental sustainability. At an international scale, FAO and United Nations European Commission for Environment (UNECE) provides for community-based watershed management approaches in planning, allocation of land, monitoring, mapping, zoning and inclusiveness (Nikiforova, 2017; Shoushtarian & Negahban-Azar, 2020). At a local level, the Forest Conservation and Management Act, No. 34 of 2016, states that in order for a forested area to be allocated

to people, it has to be de-gazetted within the provisions of environment and planning regulations adhered to strictly. Section 45(4) also prohibits any management agreement from converting a public forest into a settlement area (RoK, 2016a). The Integrated National Land Use Guidelines also regulates on protection of ground water, rivers, lakes and wetlands (RoK, 2011). Section 23 of the Water Act 2016, provides for the protection of watershed areas by establishing the areas which are vulnerable and putting in place regulations meant to protect them (RoK, 2016b). There are institutions as well meant to enforce the regulations and guidelines regarding management of watersheds such as Kenya Forest Service (KFS), Water Resources Authority (WRA) and Kenya Water Towers Agency (KWTA).

Despite the presence of standards guiding the protection of watersheds, forests are destroyed to pave way for human activities. In the Mau watershed context, people from different ethnic communities were settled in Eastern Mau as a means of gaining political mileage, without great consideration into the impacts this could have on the watersheds (Stefania & Valerio, 2018). Eastern Mau Forest Reserve is a forested area which has undergone encroachments and degradation of the watershed (KWTA, 2017). Therefore, this study assessed the impact of settlements schemes on Eastern Mau watershed.

1.3 Objectives

The objectives of this study are:

1. To examine land use and land cover changes in Eastern Mau Forest Reserve from 1979 to 2020.
2. To examine settlement schemes and boundaries in Eastern Mau Forest Reserve between 1979 and 2020.
3. To assess the impact of settlement schemes on river flows in Eastern Mau Forest Reserve from 1979 to 2020.

1.4 Research Questions

The research sought to answer the following questions:

i. How has the physical structure of Eastern Mau Forest Reserve changed from 1979-2020?

ii. Were the boundaries and settlement schemes of Eastern Mau Forest Reserve adequate to protect the catchments?

iii. What is the impact of settlement schemes on river flows in Eastern Mau Forest Reserve from 1979-2020?

1.5 Justification

Water security remains a great risk in Kenya due to poor forest resource management (RoK, 2018). One of the ways to enhance water security is protecting critical catchments that are sources of water bodies. Eastern Mau Forest Reserve is the second largest in Mau, covering 160,895 Ha, after South-Western Mau with 184,000 Ha (KWTA, 2017). In 2001, 35,301 Ha was excised in Eastern Mau which represents 54% of the area, whereas in the South-Western part, 22,797 Ha (27%) was excised to make room for farmers (Anthony, 2018). Eastern Mau Forest Reserve is the most populated block with a population of approximately 181,724 (KNBS, 2019). Eastern Mau Forest Reserve is a major water tower therefore the large tracts of land that have been cleared coupled with the settlements in it is a worrying trend. It is the second largest within the Mau Complex however it has several settlements therefore ideal as an area of study. Creation of settlement schemes in Eastern Mau began in the 1980s and further developments have followed since then hence the choice of study year as 1979 to 2020. It is essential to understand the implications of settlements schemes in a catchment to plan and manage resources well for a sustainable future.

1.6 Significance of the Study

Human settlements in catchment areas lead to land-use-land-cover changes, destruction of habitats, soil erosion, siltation and result in changes in hydrology (Newson, 2012). These problems can only be dealt with from the perspective of watershed management based on sound scientific principles and efficient technologies. It is essential to develop an approach that will aid in assessing land use land cover changes and effects on hydrological components at catchment level to aid in planning, use and management of resources (William & James, 2015). Insights into the implications of settlements on catchment and an integration of this understanding into the emerging focus of land use changes are important for the future.

The study provides valuable information through its findings and recommendations that the researcher made to government institutions and other stakeholders for implementation in order to attain a balanced outcome of human activities on catchment resources. The findings will also form the basis for planners to come up with policies that help to reduce the adverse effects of settlements on the catchment.

CHAPTER TWO: LITERATURE REVIEW

2.1 Land Use and Land Cover Changes

Land cover refers to the biophysical characteristics of the earth's surface and include soil, water and vegetation distribution (Hamad, Balzter, & Kolo, 2018). Land use refers to the interaction between humans and the physical environment with an emphasis on trends in social and economic activities, for instance transformation of an area from forested area to urban land (Hussain *et al.*, 2020). Land Use and Land Cover (LULC) changes refer to the conversion of land use types due to the interactions that occur between people and the environment. It is a major contributor towards global change with effects on the ecosystem and biodiversity (Ren *et al.*, 2019). Land use changes in forest areas are mostly a result of human activities including population pressure, expansion of agriculture and demand for wood products (Kindu, Schneider, Döllerer, Teketay, & Knoke, 2018). It also has a close relation with social economic development that is sustainable.

Detection of LULC change can be determined using trends over a certain period of time (Usman, Liedl, Shahid, & Abbas, 2015; Yan *et al.*, 2019). These trends can only be established by analysing timely spatial data over time. Remote sensing (RS) and Geographical Information Systems (GIS) are essential tools for obtaining data recorded over time and analysing them for useful information that can show the various changes over time (Mishra, Rai, & Rai, 2020). Models can also be developed and used to predict future LULC dynamics. Trends in land uses provide the basis for effective land use planning, restoration of watersheds and ecological areas and its management (Yang *et al.*, 2018). FAO defines land classes that are grouped into forest, herbaceous, grassland, shrub land, developed, agriculture, wetlands, woodlands and barren lands (Reddy & Saranya, 2017). During classification, certain land cover classes can be picked based on the dominant land cover types.

2.2 Human Settlements on Watersheds

The global population reveals a huge spatial variability with regards to settlement patterns and how they influence various ecosystems (Desta & Fetene, 2020). People have ventured into forested areas globally for various purposes including forest

resources, which has often translated to destruction of the watersheds. Watersheds lost approximately 22% of their forests from 1994-2018 globally (Perlin, 2009). Human settlement on forested areas increased from 2000-2014 by 121% leading to the reduction of forests by 64% and shrub land by 45% (Mainuri, 2018). Despite the importance of forests as watershed areas and the presence of regulations meant to protect watersheds, humans have continuously settled and destroyed forests (Acharya, Maraseni, & Cockfield, 2019; Carneiro, 2017). People are attracted to settle in forested areas due to the presence of resources and services that support their livelihoods (Larsen, 2017). Human societies have grown along the rivers and forests from 1790 to 2010 despite their vulnerability to risks such as flooding and associated impacts hence the need to define measures towards management of watersheds (James & Yu, 2019; Ashton, 2012).

The ever-increasing population leads to a demand in land for settlement and agricultural activities which drives people to settle in forested areas. The factors that drive human settlements in forested areas include economic development by the communities living around the watersheds, urbanization, increase in consumption and production patterns (Sarna-Wojcicki, Sowerwine, Hillman, Hillman, & Tripp, 2019). The interaction of humans with ecology is defined by water and forest resources (Mainuri, 2018). Politics is also a driver of settlement on watersheds where politicians use forestland as a means to gain political mileage at the expense of destruction of watersheds (Shazia, 2019). The result has been conflicts and displacement of people over different regimes owing to the importance of the forest. Degradation of watersheds in developing countries is a result of cutting down trees to pave way for land, overgrazing, over-cultivation, destruction of natural vegetation, unadjusted irrigation techniques, poor farming practices, socio-economic and political causes (Rattan, 2019).

The reduction in forest cover globally and watershed management problems has led to regulations and initiatives at different levels (Gills & Morgan, 2020). The reducing emissions from deforestation and forest degradation (REDD+) is a framework by United Nations Framework Convention on Climate Change (UNFCC) Conference of Parties to help reduce degradation of forests and enhance sustainable management (Gusti *et al.*, 2019). United Nations Environmental Programme (UNEP) has also defined approaches which integrate social and environmental values to conserve

watersheds where people have settled. The high carbon stock and high conservations values approach encourage people to live in harmony with the environment (Leijten, Sim, King, & Verburg, 2020). Other measures which have been taken to deal with human settlements in watersheds include empowering communities dependent on forests to protect them, evicting communities from forests and increasing awareness on conservation (Fang *et al.*, 2018).

2.3 Implications of Settlements on Watersheds

The destruction of watersheds leads to depletion of the water resources, degradation of land around the watersheds and soil erosion (Rattan, 2019). Trees within a watershed help to hold soil together and once degradation takes place, the immediate ecosystem is threatened (Stolton *et al.*, 2015). The other impact is decrease in stream flows due to human induced activities that lower the water table and land use land cover changes (Keesstra *et al.*, 2018). The other impact is decrease in stream flows due to human induced activities that lower the water table and land use land cover changes (Irfan & Shakil, 2013; Yaowen & Chansheng, 2017; Zhiyong, 2008). Long periods of sedimentation from soil erosion alters the water quantity and drainage patterns of rivers (Chotpantarat, 2018).

Human settlements located along rivers or near water bodies exert pressure on water quality and quantity, which affects its ecological well-being (Beatty, Cox, & Kuzee, 2018). As people move into area, there is an increase in demand of water resources. Activities such as farming further leads to erosion and increased sedimentation in the water bodies (Chotpantarat, 2018). Overexploitation of the existing water resources leads to depletion of ground water and drying up of rivers (Fang *et al.*, 2018). The growth of unplanned market and urban centres owing to an increase in population leads to pollution of rivers which affects the river quality (Wen, Schoups, & Van De Giesen, 2017).

The interaction between humans and the environment determine how watersheds are affected (Flotemersch *et al.*, 2016). As people settle near watersheds, there should be programmes aimed at conserving soil and water bodies (Newson, 2012). These programs if not available will lead to destruction of watersheds. An influx of people

into a forested area to venture in agricultural activities for instance will result in poor farming methods which lead to siltation, forest degradation and destruction of watersheds.

Natural factors such as geology, topography and climate of an area determines the impact land use will have on water resources (Alvandi, Soleimani-Sardo, Meshram, Giglou, & Ghaleno, 2021). Land use changes are the predominant factors in reduction of river runoff (Desta & Fetene, 2020). The increase in cropland areas leads to reduction of unused land and changes in retention of water (Kraff & Steinman, 2018; Lopez & Jason, 2013). The loss of vegetation from anthropogenic activities have the greatest impact on river flows (Yu, 2019; Zhiyong, 2008). Land use changes increases run-off by 13-49% and sediment yield in the river by 37-42% also depicted by the increasing levels of chemical component in the rivers (Chotpantarat, 2018).

Land use change as a result of human activities leads to a change in trend of river flows and increase variability over the high and low seasons (Yang *et al.*, 2018). The change in rivers and watershed affects the potential for planning of a region in case of natural disasters such as floods (Newson, 2012). The demand for expansion of agricultural activities and infrastructure leads to a higher demand for water (Flörke, Schneider, & McDonald, 2018). Land use changes also affect water quantity and quality while altering the ecology of a watershed (Bertule *et al.*, 2018).

2.4 Principles of Watershed Management

Watersheds, also known as water catchments encompass topographically delineated areas with rivers, streams and related drainage activities (Wang *et al.*, 2016). The management of a watershed is vital for protection of ecological, environment and social phenomenon. The principles of watershed management are based on enhancing sustainable utilization of resources (Alemu, 2016). The first principle of watershed management is that watersheds are natural systems with an integration of human and environmental factors at work (Liping *et al.*, 2018; V. R. Reddy, Saharawat, & George, 2017). Environmental factors are systems that act on watersheds without external interference, for instance, weathering processes over time (Kata, 2017). Human factors that impact watershed management include the lack of preservation of riparian zones.

The second principle is that watershed management is continuous and needs a multi-disciplinary approach to address specific restoration and protection actions (Heathcote, 2009). Watershed management requires an extensive range of stakeholders to address issues in land, water management and watershed hydrology (Alemu, 2016). Different stakeholders play different roles however it is important to synchronize their functionalities. This requires the participation of all stakeholders including communities around the watershed and institutions that manage the watersheds (Kraff & Steinman, 2018).

Watershed management support partnering, using sound science, actions and attaining results. Utilisation of land based on its capability and safe diversion of surface run-off requires the use of science that efficiently conserves the watershed (FAO, 2017; Newson, 2012). Science can be used to monitor the changes in the watershed over time in order to come up with viable solutions and plans. Stakeholders also need to take actions and measures to preserve the watershed then monitor the land-use changes and river flows for efficient utilization (V. R. Reddy *et al.*, 2017; Robertson, 2021; Tanik, 2016). A flexible approach is needed for management of watersheds with participation, gender inclusivity and empowerment, important principles (Liping *et al.*, 2018). It is important to involve communities that live around and benefit from watersheds so they are more aware of the benefit they derive and impacts of degradation of watersheds (Salah & Ward, 2008). The key is to have management of watersheds areas from the local level of communities to the relevant stakeholders, leading to integrated management (Dewata & Angraina, 2020).

Watershed management involves the proper utilization of land to its capacity so there is a balance between land and waterbodies (Getahun & Keefer, 2016; Nikiforova, 2017; Pande, 2020). This includes incorporating activities which enhance vegetation cover of the soil to avoid most of it getting into water bodies and conservation programmes. The outcome should be creating a balance between social, ecological and environmental phenomenon while enhancing sustainability (FAO, 2017). It is important to consider the various factors which could slow down efforts aimed at watershed management such as lack of participation, gender inequality and common property resources (Uniyal, Jha, Verma, & Anebagilu, 2020). The watershed management process involves monitoring and evaluating efforts aimed at management of watersheds (Wang *et al.*, 2016).

2.5 Components of Watershed Management

Watershed management involves implementing plans, programs, policies, regulations and governance which enhance the functions of a watershed (Nikiforova, 2017). The components of watershed management are based on improving the water quality and quantity and forest resources (Meshram & Sharma, 2018; Zimale *et al.*, 2017). It also includes an analysis of actions, participants of watershed management process and implementation of plans and regulations (Gusti *et al.*, 2019). Watershed management plans are developed by the stakeholders tasked with the responsibility of caring for water and forest resources, local group and corporations (Asgari, 2020).

Watershed management is based on policies and regulations that guide user rights, protection of water resources and management of water supply (Zhang, Chen, & Yao, 2015). There are acts, policies and regulations at national, regional and international level designed to aid with management of watersheds (Pande, 2020). Governance of watersheds incorporates the social, political and administrative systems which define the use and management of watersheds (Alvandi *et al.*, 2021; Murphy & Sprague, 2019). It also determines how resources are used efficiently and distribution, with an aim of creating a balance between water use and ecosystems.

2.6 Watershed Management Approaches

There are two approaches to watershed management; participatory and adaptive (Dodds, 2020). The participatory watershed management approach involves the local community and stakeholders in planning and formulating policies and action plans for management of water and forest resources (Kraff & Steinman, 2018) . The approach aims at defining activities which improve livelihood strategies of the community through collaboration with stakeholders and enhancing traditional forest management and community networks. Through this approach, stakeholders can develop policies and plans with communities so that they can have control over natural resources around the watershed (Tesfaye, Debebe, & Yakob, 2018) .

The adaptive watershed management approach lays emphasis on creating a balance between ecological, economic and social changes in land use in a watershed (Pande,

2020) . Various components of watershed management can be integrated into defining management strategies that enhance sustainability. This results in long term protection and restoration of natural resources (Hubbart, Kellner, & Zeiger, 2019) . The approach classifies critical watersheds that require conservation, identifies threats to protection of resources and develops recommendations that ensure the action plans are viable (Esmail & Geneletti, 2017; Pande, 2020). Stakeholders can then formulate recommendations based on land use impact mitigation and protection of water and forest resources.

2.7 Research Gap

Watersheds provides various services that are beneficial to people, animals and the environment hence need to be protected. There were more than 2000 articles, 1000 relevant to the study but 80 were used for review since they contained information on watersheds and their management. Various studies and reviews have focused on impact of human activities on rivers (Desta & Fetene, 2020; Dewata & Angraina, 2020; Gashaw *et al.*, 2018; Getahun & Keefer, 2016; Masuma & Adullah, 2020; Murphy & Sprague, 2019; Tesfaye *et al.*, 2018) and forests (Hussain *et al.*, 2020; Keesstra *et al.*, 2018; C. S. Reddy & Saranya, 2017; V. R. Reddy *et al.*, 2017; Sarna-Wojcicki *et al.*, 2019; Stanganelli, Torrieri, Gerundo, & Rossitti, 2020; Uniyal *et al.*, 2020). However, there has been little research done on how rivers and their flows are affected by establishment of settlements in the watersheds, which this study focused on.

2.8 Conceptual Framework

The conceptual framework shows the link that exists between various factors in the study. It focuses on the functioning of the watershed with various factors such as human settlement and river flows. The driving forces of watershed degradation in the reserve are human activities that affect land use and land cover. (Acharya *et al.*, 2019; Shoushtarian & Negahban-Azar, 2020). The importance of the forest reserve as watershed is based on its rivers, wetland and precipitation (Carneiro, 2017). The intervening variables, which are in the form of regulations and policies that inform decisions made to manage the watershed. These decisions have a great impact on the land use land cover and river flows (Figure 2.1)

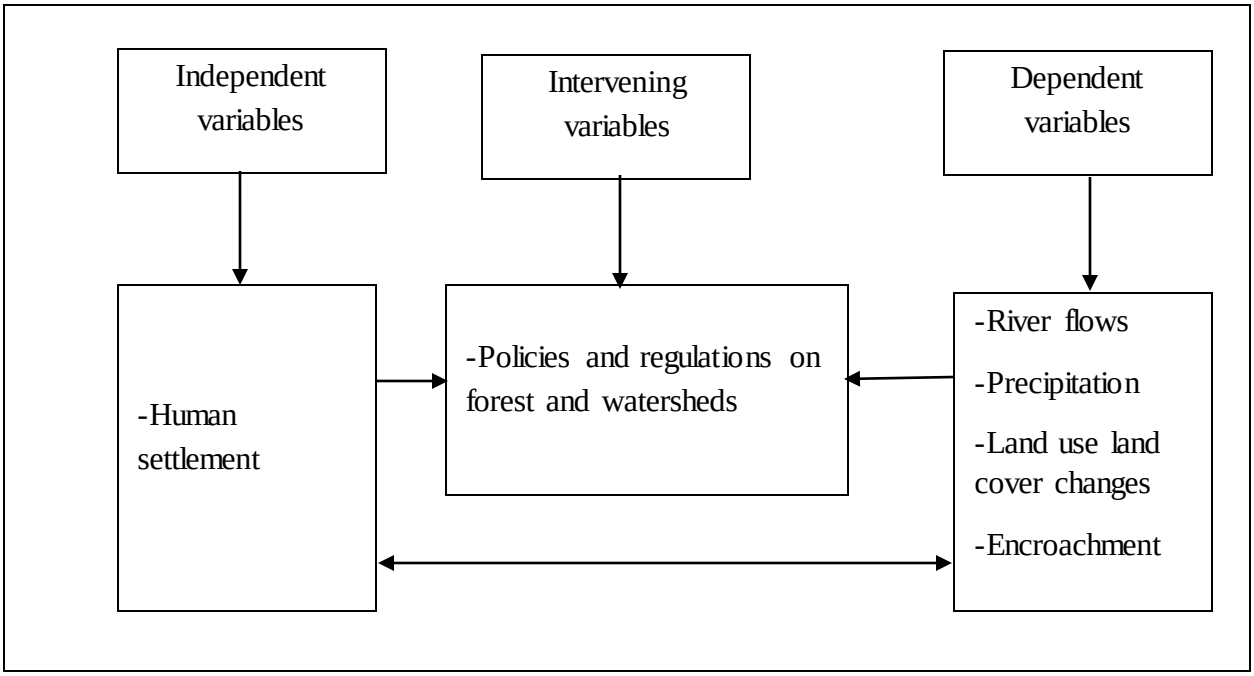

Figure 2.1: Conceptualizing land use changes and watersheds

(Adapted from Ngeno, 2016)

CHAPTER THREE: METHODOLOGY

3.1 Study Area

Mau Forest is an indigenous montane forest complex in the Rift Valley region of Kenya covering an area of 273,300 Ha. It is made of 22 blocks extending into the counties of Nakuru, Narok, Kericho, Bomet, Nandi, Baringo and Uasin Gishu as shown in Figure 3.1. Eastern Mau Forest Reserve in Nakuru County makes up one of the two largest blocks and covers approximately 160,895 Ha with 67,335 as a gazetted forest and 93,560 covering the 5-kilometer buffer zone (KWTA, 2017).

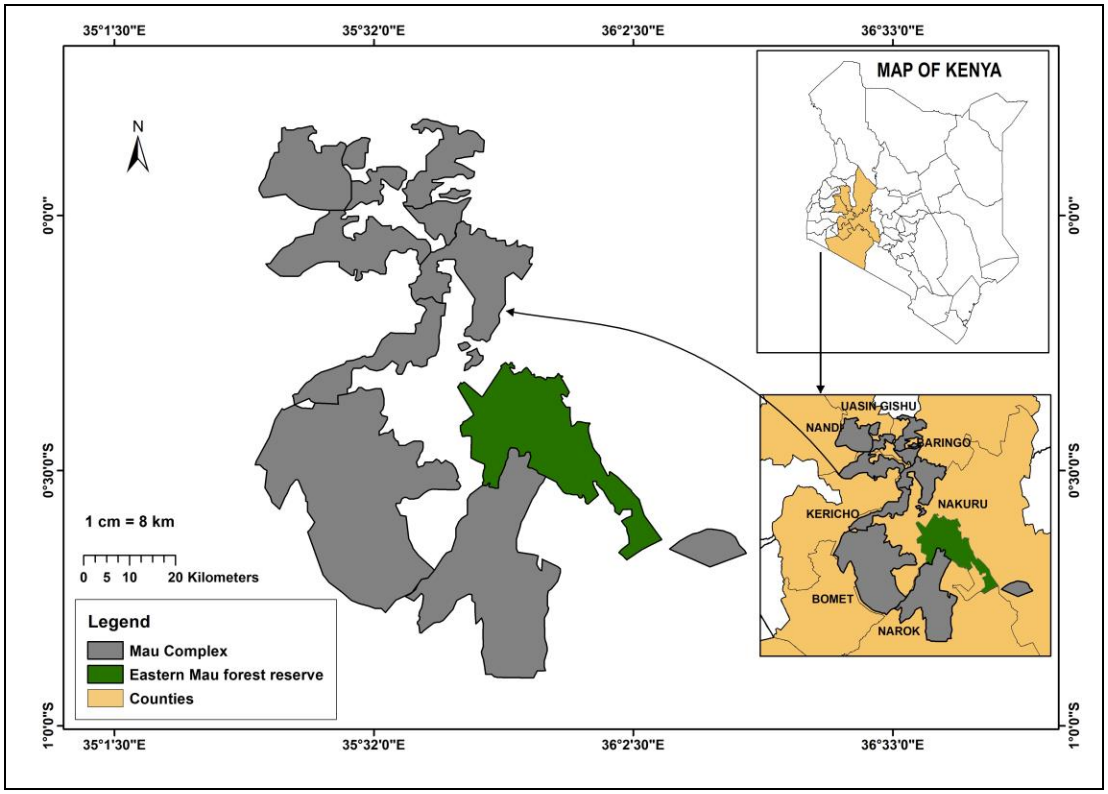

Figure 3.1: Location and extent of Eastern Mau Forest Reserve

Kenya Water Towers Agency (KWTA) has divided the water tower into four main sub-catchments within the forest namely Upper Enderit, Makalia, Njoro and Rongai. These areas face numerous issues which threaten its existence including deforestation and cultivation along the river bank (Kweyu, Kiemo, Emborg, & Gamborg, 2019). The rainfall in Eastern Mau Forest Reserve ranges between 1000-2000mm per annum with the long rains experienced between March and May while short rains are between July and September (Tarus, Kirui, & Obweyere, 2019). It has a temperature range of 12-27°C with the coldest month as July. It has deep, fertile, volcanic soils which are good

for agricultural activities. Eastern Mau Forest Reserve is the source of rivers; Njoro, Molo, Naishi, Makalia and Rongai (KWTA, 2017).

3.2 Research Design

The study adopted a descriptive research design. Descriptive research seeks to obtain information to systematically describe a situation or problem. The variables are only identified, measured and observed (Creswell, 2009). The choice of descriptive study was informed by the fact that it is not only restricted to fact findings, but often result in the formulation of important principles of knowledge and solution to significant problems (Julie & Scott, 2011). It is designed to obtain information concerning the current phenomenon and wherever possible to draw valid general conclusions from facts discussed. It also provides an approach for developing instruments that are more context specific in gathering the required information about the research topic. For the study, quantitative research was carried out by statistical analysis of the data collected on river flows and text analysis whereas qualitative research was attained through historical study of maps in Eastern Mau and in-depth interviews.

3.3 Sampling Size and Sampling Procedure

The target population was government institutions in charge of resources in Eastern Mau Forest Reserve. The area under study covers five wards within Nakuru County; Elburgon, Mariashoni, Mauche, Nessuit and Njoro with a total population 133,436 (KNBS, 2019). The study utilized a number of techniques to obtain its objectives. Primary data collection was derived from key informant interviews and observation. Secondary data was derived from GIS and remote sensing data and maps. Purposive sampling was used to select key informants from the different institutions; Ecosystem Conservator Nakuru, Deputy Technical Coordination Manager Rift Valley Basin Area, directors from National Environment Management Authority (NEMA), Environment department, Kenya Meteorological Department, Environment and Physical Planning, all based in Nakuru County.

3.4 Data Collection

Primary and secondary data was collected for the study. Key informant interviews were conducted at the identified institutions where relevant personnel were interviewed based on their involvement regarding management of Eastern Mau Forest Reserve. Secondary

data was obtained from maps of settlement schemes, boundaries gotten from Survey of Kenya and reviewed articles, books and journals. To examine land cover changes in Eastern Mau Forest Reserve from 1979-2020, Landsat satellite data was obtained from Earth explorer, an open source of data. Landsat images were obtained over an interval of 10 years from 1979 to clearly define the rate of change over the years. Landsat data has good imagery with great resolutions hence its choice for use in the study.

The downloaded images were of November 1979, March 1989, October 1999, June 2009 and May 2020. It was not possible to use images from the same month due to a high cloud cover and erroneous scan lines in some months. The implication of this was systematic data gaps hence only months with high resolution images were used. Data on river flows from River Njoro was obtained from Water Resources Authority Office in Nakuru county for the period 1979 to 2020. River Njoro forms the biggest catchment of Eastern Mau Forest Reserve hence used as a predictor for river flow changes. Rainfall data was obtained from Nakuru Meteorological Station for 1979 to 2020. Confidentiality was enhanced by assuring the interviewees that the information provided would be used for academic purposes only. A research permit was obtained from National Commission for Science Technology and Innovation (NACOSTI) to carry out the research.

3.5 Data Analysis

The images obtained from Landsat are analysed based on supervised classification method using the Maximum Likelihood Function from ArcGIS. Supervised classification makes it easy to define the number of classes that will have substantial results for the study (Hamad *et al.*, 2018). Classification also makes it easier to define the percentages in different land use changes over the years. Time Series Analysis was used to understand the trend in river flows over time whereas Pearson correlation was used to determine relationship between farmlands and river flows. Content analysis was used to analyse data from key informant interviews, reports, regulations and laws. Trends are established for five classes after classification of Landsat images; dense vegetation, woodlands, farmlands, grasslands and settlements. Table 3.1 shows the description of classification classes.

Table 3.1: Description of land cover classes

Class	Classification Description
Dense vegetation	An area of dense trees and vegetation which form a canopy mostly made up of indigenous trees
Woodlands	An area of trees and vegetation which do not form canopies. It can have both indigenous and exotic trees
Farmlands	Area used for cultivation of crops with rural settlements
Grasslands	Area with grass as dominant vegetation

Source: Adapted from Reddy & Saranya (2017).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the results and key findings from the study. The sections are based on the objectives, which are:

1. To examine land use and land cover changes in Eastern Mau Forest Reserve from 1979 to 2020.
2. To examine settlement schemes and boundaries in Eastern Mau Forest Reserve between 1979 and 2020.
3. To assess the impact of settlement schemes on river flows in Eastern Mau Forest Reserve from 1979 to 2020.

4.2 Land Use and Land Cover Changes in Eastern Mau Forest Reserve

The land cover changes in Eastern Mau Forest are shown in Figure 4.1 and Table 4.1for the last four decades from 1979 to 2020. In 1979, the forest was covered mostly with dense vegetation and woodlands, with a few spots of farmlands spread across the forest reserve while in 2020, farmlands are more dominant. Between 1989 and 2009, there is a decline in dense vegetation and increase in farmlands. In contrast, there is a slight increase in dense vegetation spread out across the areas that had been occupied by farmlands in 2020. In Figure 4.1 and Table 4.1, the forested areas which have dense vegetation have been decreasing from 1979 to 2009 gradually with a slight increase in 2020. Dense vegetation decreased by 42.7% from 96896 Ha to 30572 Ha in the period 1979 to 2020. During the same period, farmlands increased from 7309 Ha to 68547 Ha which represents 41% increase.

The greatest decline in forest vegetation cover and increase in farmlands is between 1979 and 2009. This is the period when settlements schemes were set up in the forested areas, which were in late 1980s and early 1990s as well as forest excisions in early 2000s. There has been a significant increase in area under dense vegetation and decrease in farmlands in 2020 due to the efforts in place by various institutions to restore the watershed. Woodlands have slightly increased over the years by 6.7% with the greatest increase between 1979 and 1989, followed by a decline till 2009 and further increase in 2020 due to reforestation and natural restoration. The area under grasslands has

continually remained low over the years. There has been an increase by 3.4% from 18019 Ha to 12726 Ha between 1979 and 2020. The area under forest cover has declined by 59661 Ha, which is a substantial loss given the importance of Eastern Mau Forest Reserve as a major watershed forming the Mau Complex water tower.

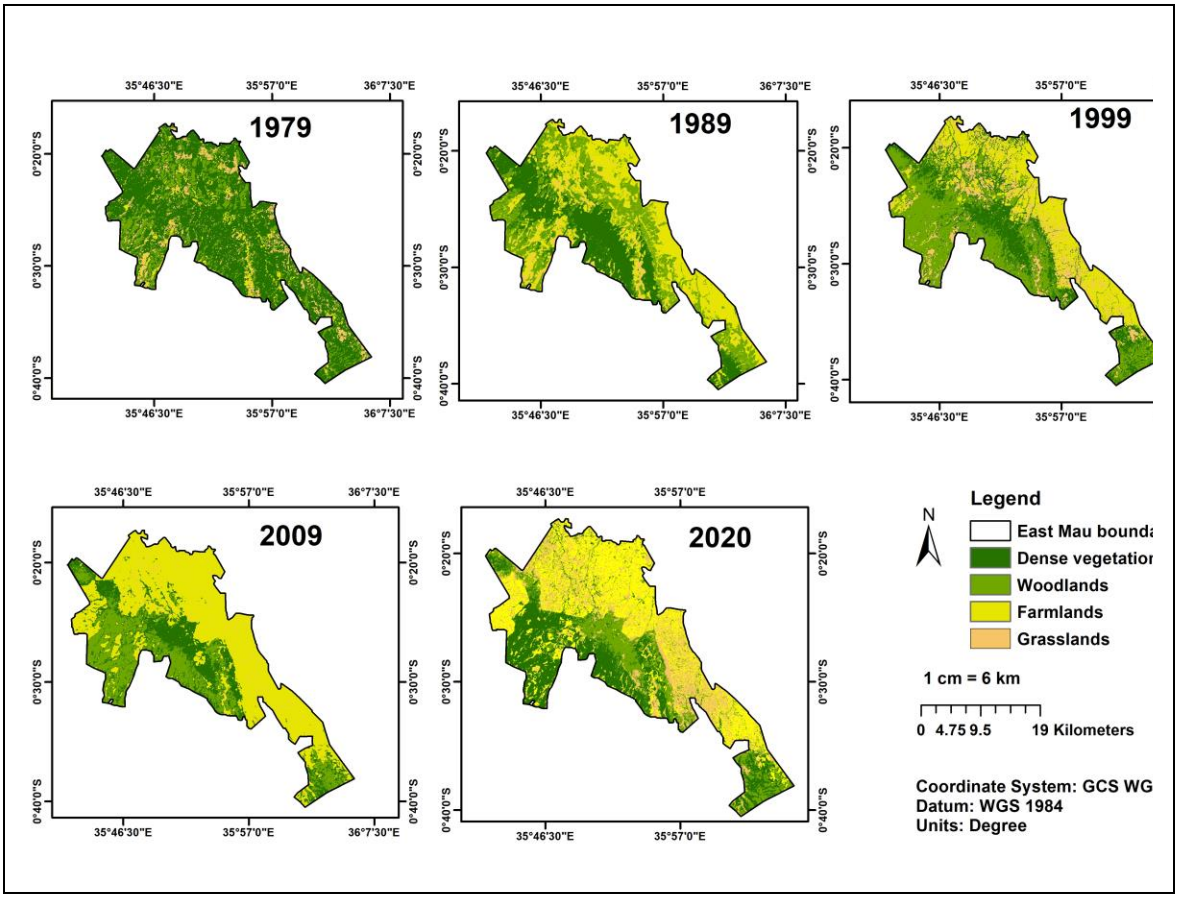

Figure 4.1 Land use trends in Eastern Mau forest reserve from 1979 to 2020

Table 4.1: 10 year land cover change in Eastern Mau Forest Reserve from 1979-2020

Land Cover Type	1979		1989		1999		2009		2020	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Dense vegetation	96896	61.7	61794	39.1	50157	32.9	30572	19	37208	20.3
Woodlands	37964	23.7	53187	33.6	43138	28.1	33334	21.0	45744	30.4
Farmlands	7309	4.6	39546	25.0	45605	29.7	89549	56.3	65547	42.7
Grasslands	18019	11.3	3592	2.3	14455	9.4	3965	2.5	12726	7.9

Figure 4.2 shows the fluctuations in land cover changes over time. Grasslands is the least fluctuating land cover. There is an inverse relationship between dense vegetation and farmlands since an increase in farmlands leads to a decrease in dense vegetation and vice versa. The woodlands have slight fluctuations over the years with a significant decline till 2009 and increase in 2020. The woodlands are found inside the forested areas or within settled areas whether planted or natural, but do not form canopies. In 2009, the area under farmlands was at its highest and dense vegetation was at its lowest. This changes after 2009 due to interventions aimed at restoring the reserve. The decade between 2010 and 2020 is characterised by a slight increase in dense vegetation cover and slight decline in woodlands and farmlands.

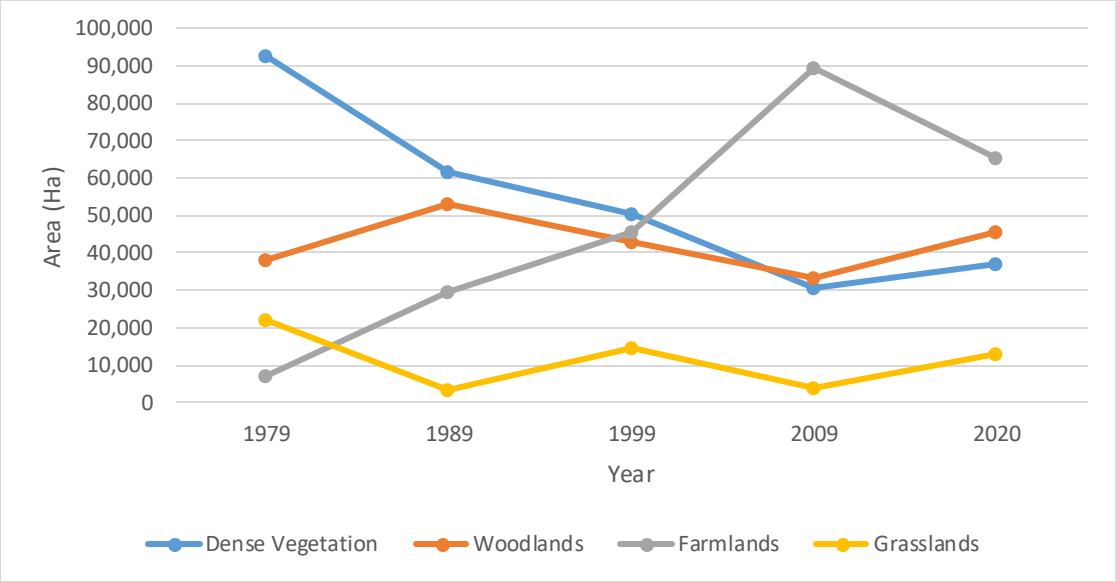

Figure 4.2 Land Use Land Cover Changes in Eastern Mau

The common land cover types found in Eastern Mau forest reserve are forest, farmlands and patches of grasslands as shown in plate 4.1. People engage in commercial and subsistence farming such as growing of crops such as potatoes, maize and beans, livestock keeping and tea plantations. Increased human population in the reserve has led to intensification of land use and exploitation of wetlands and forest resources. Farming is carried out throughout the year with household labour commonly used. The areas which are currently forested are dominated by indigenous tree species and form canopies (Anthony, 2018). In the areas where deforestation has occurred, eucalyptus and cypress are dominant tree species, planted along the edges of farms to act as

windbreakers. The results are similar to those obtained by Desta and Fentene (2020); in their study, land cover changed drastically from forested to farmlands as people engaged in farming activities. The area within the watershed was diminished as settlements took over. The same is evident in Eastern Mau Forest Reserve as area under dense vegetation has been taken over by settlements and farms.

Plate 4. 1: Overview of Eastern Mau with forest area, grasslands and farmlands

The government in conjunction with various institutions have put in place efforts meant to restore some of the deforested areas. KWTA recognizes the importance of Eastern Mau as a major water tower forming the Mau Complex. It recognizes the threat to Eastern Mau and other water towers and has put in place restoration initiatives in partnership with different stakeholders including Kenya Forest Service (KFS) to increase tree planting and reclaim forestlands. These efforts include creation of a multi-stakeholder task force comprising various stakeholders such as KFS, Kenya Wildlife Service (KWS) and the community members (RoK, 2018). Specific interventions by KWTA include building a forest guard outpost, community capacity building, land recovery efforts that has seen 44 titles totalling 1,250 ha being surrendered voluntarily as of 2019. Other interventions include, bamboo planting, promotion of agroforestry in Sururu and Molo areas among close to 10000 farmers and encouraging alternative sources of livelihoods such as modern bee-keeping and use of energy saving jikos to reduce dependency on forests (KWTA, 2020). Other efforts include surveying and mapping of forest cut lines and boundaries.

KFS has been at the forefront in implementing activities and programs meant to protect Eastern Mau. It has engaged stakeholders and the community in tree planting exercises in the forested areas, creating awareness among the public regarding the importance of forests and watersheds, encouraging creation of community forest associations (CFAs) and implementing conservation programs. In an effort to restore some of the degraded areas, KFS in conjunction with the Ministry of Environment and Forestry has evicted families who live in some of the forested areas.

4.3 Settlement Schemes in Eastern Mau Forest Reserve

Kenya's land issues began before independence and continued at post-independence to current era. Before independence, prime agricultural areas were allocated to white settlers who used them for agricultural purposes, ranches or mixed farms (Kimaiyo, 2004). When Jomo Kenyatta took over, lands held by the white settlers were acquired by the government of Kenya using loans from the British Government and World Bank (RoK, 2004a). These lands were later distributed under settlement schemes in the 1960s and 1970s with the target being Kenyan smallholder (RoK, 2004b). There were few land titles allocated during this time hence most schemes remained unregistered. When Moi took over in 1978, there were new strategies of state directed creation of settlement schemes (Anthony, 2018). In the mid-1980s, more people were allocated land in Mau Forest by the government.

Settlement schemes in Eastern Mau began in the late 1980s and early 1990s as a political move to settle communities by KANU regime under President Moi. The result is massive destruction of the forests to pave way for settlements and agricultural activities (Klopp, 2012). In 2001, over 200 km^2 of the forest was excised by the government following a Gazette Notice No. 889 of 16th February 2001 (RoK, 2012). The lack of a buffer system to deter further encroachment has prompted people to extend farm boundaries, thus encroaching into forest reserve. These excisions has been the greatest threats to Eastern Mau as it opened up forests to encroachment and degradation (Njuguna, Mbegera, & Mbithi, 1999).

The creation of settlement schemes in the forest following a Presidential Directive by Moi in the 1985 did not have any legislative support; but enforced by the Minister under the Forest Act (Boone, Lukalo, & Joireman, 2021). The result was de-gazettement of large tracts of land in Eastern Mau to pave way for settlements, which led to the creation of Mariashoni and Nessuit in 1986 (Table 4.2). In 1995, there was a directive for excisions in Eastern Mau that saw 40,000 people settled and creation of Teret, Likia and Sururu schemes (RoK, 2004b). The Presidential directives did not have legal notices to support it as it was only done by word of mouth (Albertazzi, Bini, Lindon, & Trivellini, 2018). On 15th October 1997, there was a court injunction to stop further allocation of land. However, one month later, President Moi issued titles to the people settled in the schemes (Veit, 2019). Excisions was done also in 2001, that led to the creation of Baraget and Elburgon settlement schemes (Table 4.2).

Presidential directive was given in 2014 to introduce the Mau buffer project aimed at protecting the Mau ecosystem (Wanderi, 2020). The impact was creation of a forest buffer belt around the forest areas to deter people from moving further into the forested areas (RoK, 2009). In 2020, another directive was given to issue 5-acre titles to persons living in Eastern Mau and block title to Ogiek community to resolve long-standing conflicts; but this was halted by the Environment and Lands Court in Nakuru. This was as a result of petition filed on behalf of Mau Ogiek Community by Ogiek People's Development Program and Ogiek Council of Elders (Ogiek People's Development Program, 2020).

The plans for settlement schemes and excisions for Eastern Mau Forest Reserve made in 2001 are in existence. However, people in the schemes have encroached beyond the delineated boundaries (RoK, 2004a). The settlement schemes within the reserve did not follow procedures of altering forest boundaries before titles were given, hence they are considered as irregularly established as stated in the Forest Act Cap 385 (Boone, 2012). The Act was aimed at protecting the forests, but also provided for alteration of forest areas by the Minister by giving a 28-day notice and gazetting it. There are seven settlement schemes in Eastern Mau Forest block that were established irregularly namely Sururu, Likia, Teret, Nessuit, Elburgon, Mariashoni and Baraget.

Table 4.2 shows how the settlement schemes were established and acreage. The impact of creation of settlement schemes within a forest area include further encroachment to increase agricultural land and reap from a fertile area (Njuguna *et al.*, 1999). This has led to further destruction of forest and water resources without consideration of importance of the reserve. It also opened up the area for illegal logging and destruction of bird and animal species together with their habitats (Boone, 2012).

Table 4.1 Establishment of Settlement schemes in Eastern Mau Forest Reserve

Schemes	Year Established	Establishment process	Area (Ha)	Number of beneficiaries
Mariashoni	1986	Presidential directive	3600	178
Nessuit	1986	Presidential directive	2693	133
Baraget	2001	Excision	2122	105
Elburgon	1986	Presidential directive	3361	166
Teret	1995	Excision	2619	129
Likia	1995	Excision	1751	86
Sururu	1995	Excision	2380	117

Mariashoni and Nessuit settlement schemes were established in the late 1980s with an aim of settling different communities, to garner political mileage. The forest land became a new frontier for Moi's political base. The settled areas became constituencies which looked up to the regime dignitaries hence build-up of political support (Boone, 2012). Elburgon was also established in the 1980s to extend Elburgon Township. Teret, Sururu, and Likia schemes were established in 1995 to settle Ogiek after eviction from their ancestral land (Kimaiyo, 2004). Baraget scheme was established in 2001 following the directive for excisions (Njuguna *et al.*, 1999). The beneficiaries were meant to be the Ogiek and landless people, however, the people who benefitted mostly include government officials serving in various capacities, politicians and leaders who allocated themselves huge parcels of land (Stefania & Valerio, 2018). The average area allocated to each person in the settlement scheme is 2.02 Ha, but political affiliates of the President got huge parcels, ranging from 10 to 50 Ha (RoK, 2004a). People have encroached beyond the settlement schemes and continue to destroy the forest.

Figure 4.3 shows the boundaries of settlement schemes in Eastern Mau Forest Reserve. The encroached area of 12,968 Ha was not within the boundaries of settlement schemes, but people have settled in them. When settlement schemes were created, there was lack of clear boundaries to demarcate their extent. People have encroached into the forested areas over time, further stretching the boundaries. There are no fences or beacons which could clearly indicate the boundaries and deter people from venturing into restricted forest reserve areas. The lack of constant monitoring and need to feed an increasing population curtailed these efforts aimed at conserving the reserve (Njuguna *et al.*, 1999). Harvesting of trees for timber, firewood and charcoal was also a contributing factor towards the encroachment into forested areas.

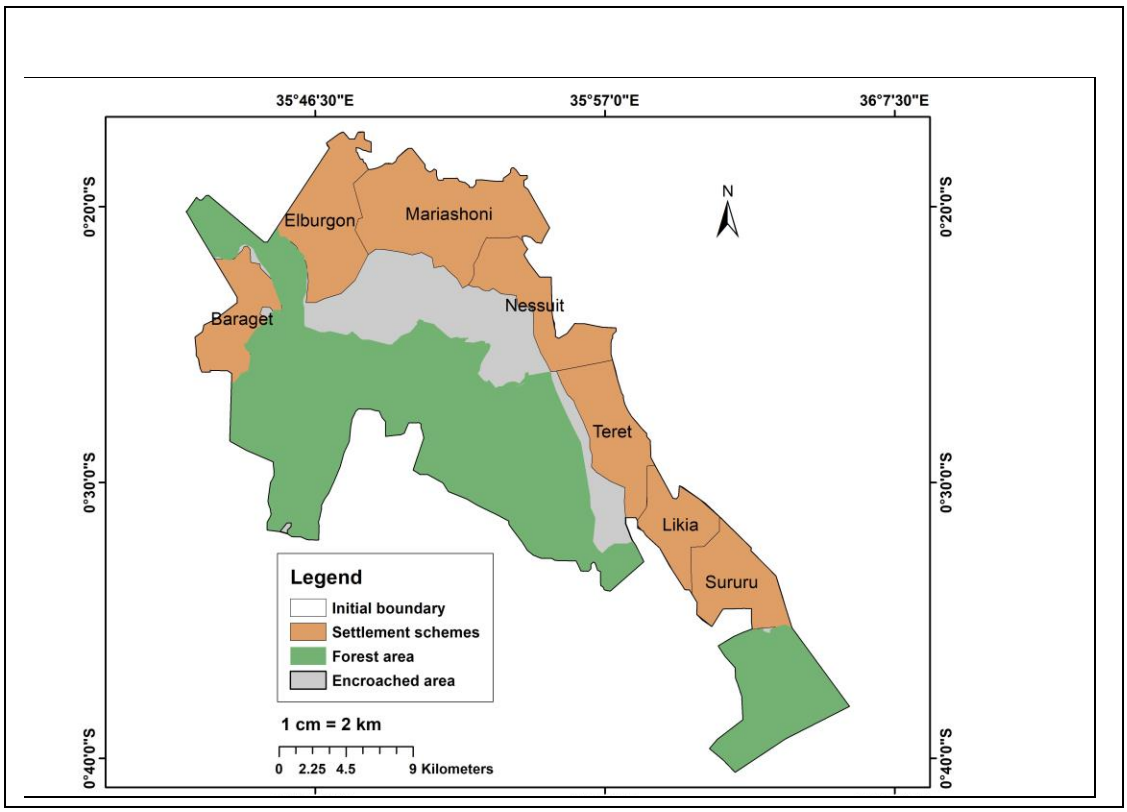

Figure 4.3: Settlement schemes in Eastern Mau Forest Reserve

The results obtained are similar to those obtained by Getahun and Keefer (2016); in their study, settlements can spread fast over the years to protected forests and watersheds. As people engage in agricultural activities the demand for fertile and productive land increases. A lack of policies and regulations meant to deter people from crossing into the watershed can lead to encroachment and destruction of forests. Even with regulations in place, constant monitoring to deter people from encroaching as seen

in Eastern Mau Forest Reserve. Agriculture is the greatest contributor towards destruction of watersheds (Carneiro, 2017). Once people encroach into watersheds, the settlement patterns and subsequent implications can be tracked over the years.

4.3.1 Eastern Mau Forest Reserve Cutlines

The non-procedural creation of settlement schemes led to the introduction of cutlines in Eastern Mau Forest reserve. There are various imaginary boundaries in the name of cutlines meant to suit varying interests of groups (Figure 4.4). The cutlines however, present an informal situation, acting as a replacement of formal survey and demarcation of the forest boundary. The irregular settlements of people in the forested area began without proper survey and alteration of forest boundaries. The presence of several imaginary boundaries has led to further encroachment of the forested areas with conflicts between community and leaders arising with each action taken towards restoration of the area (Kweyu, 2012). The creation of one official cutline is still under survey to determine current extent of the forest boundary. Figure 4.4 shows the boundaries of Eastern Mau forest reserve over time. The proposed boundary follows the boundary of settlement schemes after Presidential directives and excisions. People who had encroached the forest are inside the proposed boundary and therefore likely to be displaced.

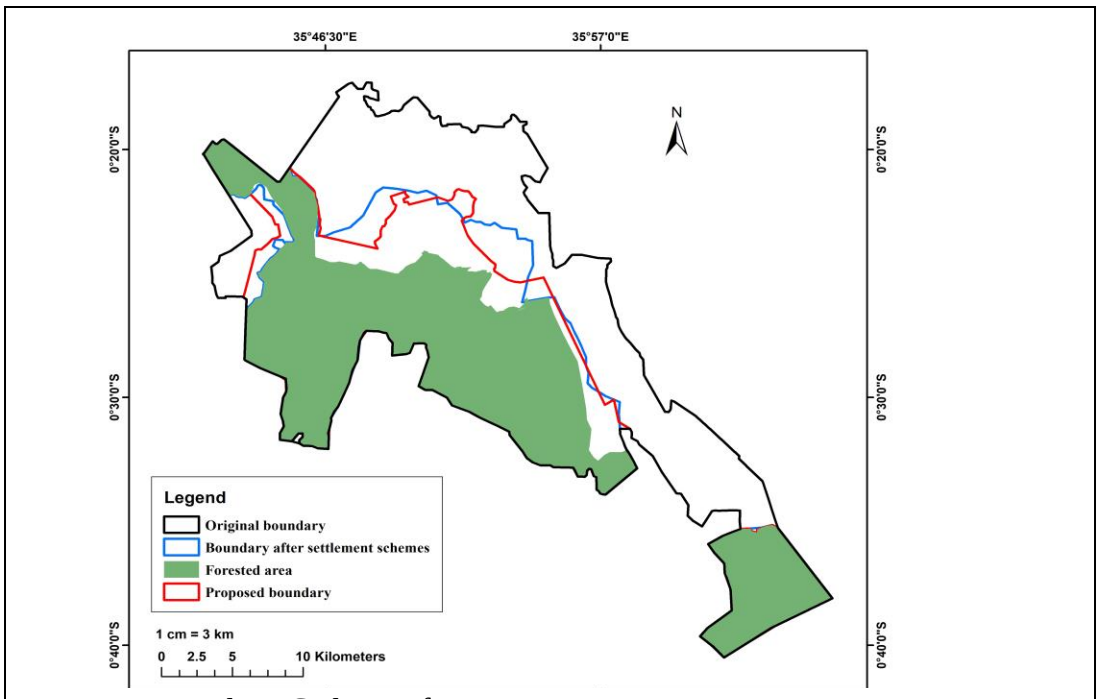

Figure 4.4: Boundary Cutlines of Eastern Mau Forest Reserve

The proposed boundary gets into some of the areas within the boundary after excisions. This is due to the fact that some areas are critical areas that need to be protected. The people within these affected areas will be allocated land elsewhere outside the forested area to avoid tensions among people already living within the existing boundaries. The lack of a definite barrier to deter people from encroaching further into the forest and presence of several imaginary cut lines makes it hard to determine how to balance the situation without causing further tensions. The rationale for creation of cutlines was to draw a boundary between forest and settlement schemes and deter further encroachment and destruction of the forest. The boundaries did not have a definite barrier system to deter encroachment such as tea zones or fences (Kweyu, 2012). The cutlines have shifted over time to accommodate the various people who have moved into the forested areas and avoid conflicts between settlers and agents being tasked with the responsibility of preserving the forest. The cutlines have moved inwards into the forested area over time, to accommodate more people.

The encroachments into the forested area started after 2001 and continued gradually till evictions of people started. The realization of the importance of Eastern Mau forest reserve as a watershed and threats that it faces has led to efforts meant to restore it (KWTA, 2017). The first attempt at evictions were between 2004 and 2006 however they were not successful as people went back to the forest afterwards, due to inadequate measures that would deter them from heading back (RoK, 2009).

The second phase of evictions was in 2009, where more than 40,000 people that are considered to have encroached into the reserve were displaced (Human Rights Watch, 2020). This follows an aggressive campaign by various groups to reclaim and protect the forest reserve. The refusal by some people to move out of Eastern Mau has led to use of force by the government in their evictions, leading to conflicts. It has caught the attention of the international community, leading to the rise of conflict with regards to the social and environmental dimensions of the reserve (Ogiek People's Development Program, 2020).

The next phase of evictions within the encroached area took place in 2018, with an aim to restore the forest reserve. It led to eviction of more than 5,000 families. The

government resorted to evictions as a means to remove people forcefully out of the reserve. The following phase of planned evictions from Eastern Mau forest reserve targets close to 60,000 people living in the encroached areas of the forest as they are considered to have settled illegally in the reserve. The evictees and human rights groups have cited the use of excessive force by the government as houses were burnt down and crops torched down. The result is creation of camps, loss of lives and property (Human Rights Watch, 2020).

The frequent and endless conflicts in Eastern Mau have led to the displacement of local residents and destruction of property around the vicinity. In June 2020, the Cabinet Secretary for Environment and Forestry, Mr. Keriako Tobiko stopped the evictions of people from Eastern Mau until the official cutlines are determined (Human Rights Watch, 2020). The people who live outside these cutlines will be evicted. There are people with title deeds living within the reserve while there are others with fake title deeds, which they use so that they are not evicted from the forest.

4.4 Impact of Settlement Schemes on River Flows in Eastern Mau Forest Reserve

Eastern Mau Forest Reserve is the source of the following rivers: Njoro, Nderit, Makalia and Naishi; which flow into Lake Nakuru, the home of flamingos and Molo, which feeds into Lake Baringo, another habitat for flamingos. The rivers and lakes are important habitats for plant and animal species and provide water for rural and urban settlements in Nakuru and Baringo counties. The tributaries of the Mara River that drain into Lake Victoria also stem from Eastern Mau (KWTA, 2017). Eastern Mau Forest Reserve is a watershed due to the rivers, streams and wetlands it has as shown in Figure 4.9.

4.4.1 Rainfall Changes

To understand how human settlements have affected river flows, it is important to understand the trends in rainfall in the forest reserve over time as well as the condition of the rivers and streams in Eastern Mau. Figure 4.5 shows the changes in rainfall from 1979 to 2020 with a 2-year moving average. Generally, there has been an increase in rainfall over the years with 2020 recording the highest rainfall amounts followed by 2011 and 1999 being the lowest. There has been swings in rainfall due to climate

variability (Kevin, 2015). Eastern Mau forest reserve has also been recording an increase in rainfall over the years.

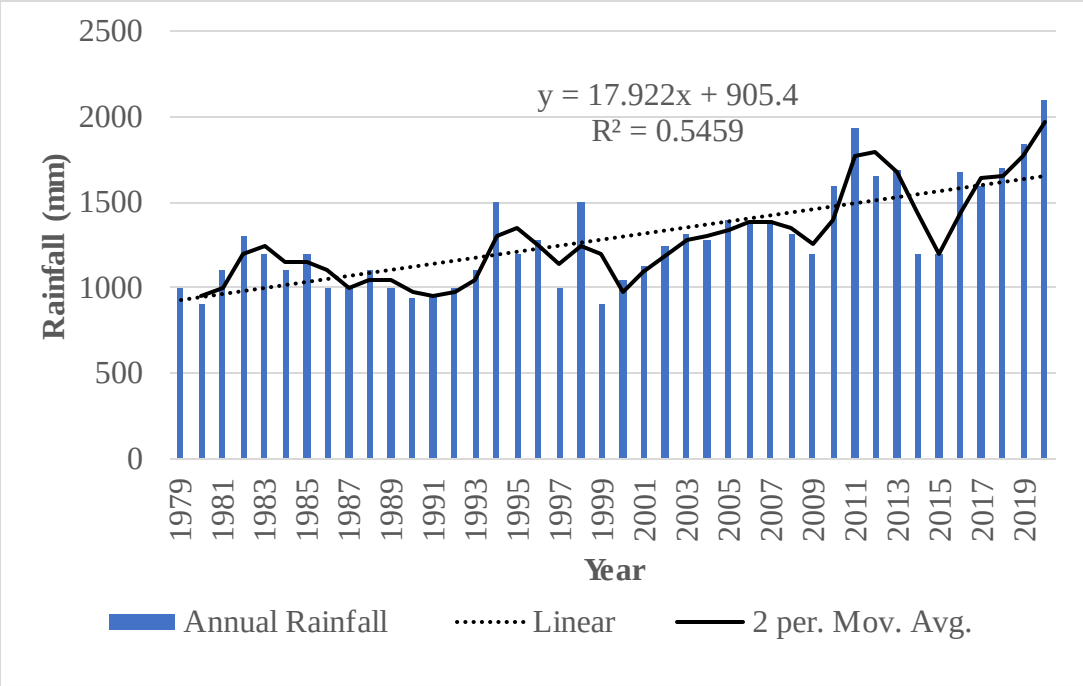

Figure 4.5 Rainfall trends in Eastern Mau from 1979 to 2020

Figure 4.6 shows the annual rainfall variance in Eastern Mau Forest Reserve. The mean annual rainfall is 1290.71 mm with a standard deviation of 297.57 mm. 2020 has the highest positive variation with 2003, 2004 and 1996 recording a significant negative correlation. The rainfall variance keeps swinging over the years however between 2001 and 2009, there is a significant dip that changes after 2010 up to 2012. Between 2012 and 2015, there is a continuous decline and a positive variance from 2016 to 2020.

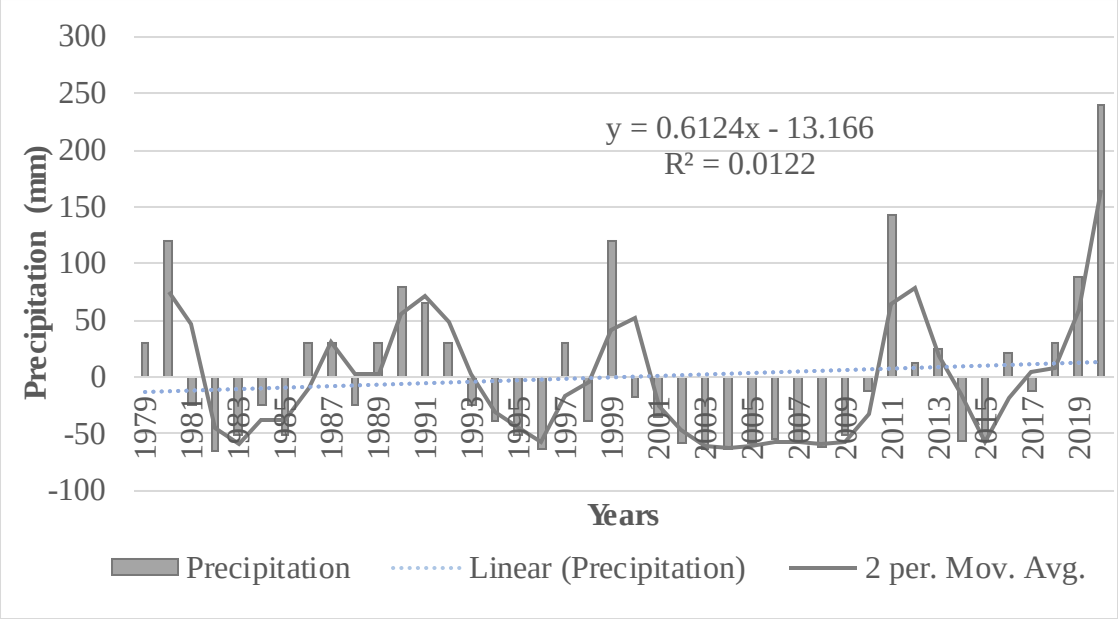

Figure 4.6 Annual precipitation variance in Eastern Mau from 1979 to 2020

The data on river flows for river Njoro was obtained from 2FC11 gauging station from January 1979 to December 2020. Eastern Mau Forest Reserve is a source of several rivers however river flow data for river Njoro is available and consistent throughout the years. The mean annual and monthly river flows are used to determine the changes in river flows over the years. The mean annual river flows are tabulated alongside the mean annual rainfall obtained from Molo Forest Station in Figure 4.7.

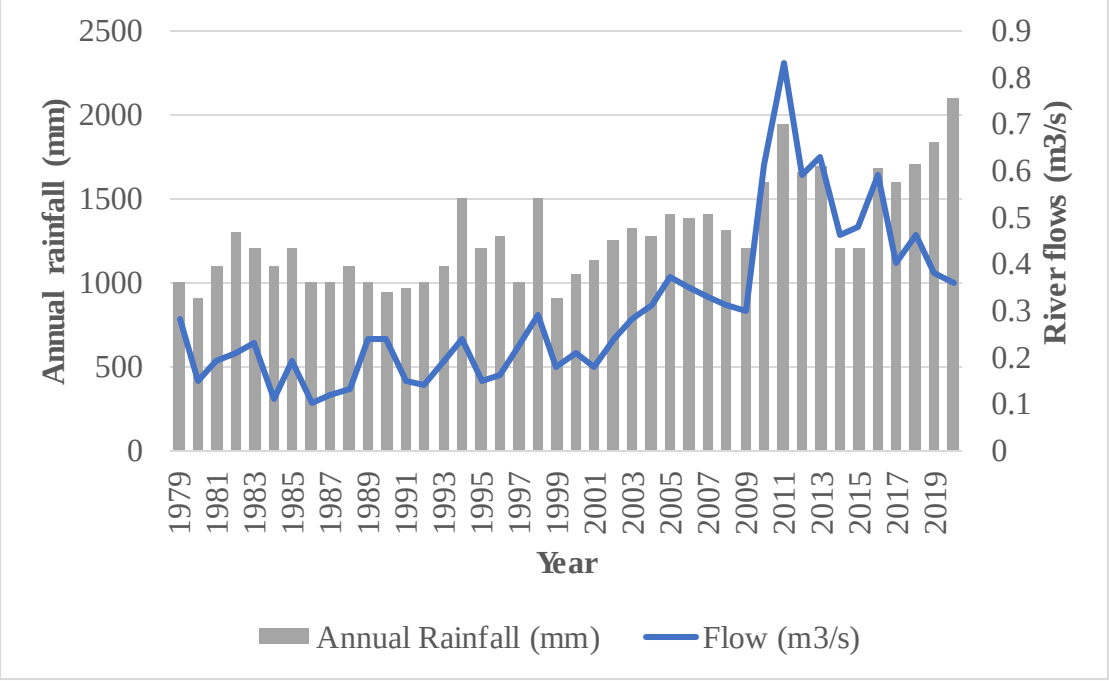

Figure 4.7 Annual rainfall and river flows in River Njoro

The mean annual rainfall and river flows from Figure 4.7 indicate that there have been significant changes in the rainfall and river flow in River Njoro. The highest rainfall and river flow amounts are recorded in 2020 and 2011 with 1940mm and 0.83m^3/s respectively. 1980 and 1989 recorded the lowest rainfall amounts of 900mm and 1986, the lowest annual flow of 0.1 m^3/s. There has been consistent change in the river flows between 1979 and 2001. This was marked by a gradual increase from 2001 to 2011 with peak flows in 2011. There has been a general decline in river flows from 2011 to 2020.

The rainfall annual between 1979 and 1998 recorded a consistent increase then decline in rainfall amounts over the years. The river flows during the same period recorded a swing that was defiant of rainfall patterns. Between 1979 and 2009, the river flows are at lower levels in comparison to rainfall levels. Rainfall and river flows have been in direct proportion in most years until 1999. The changes after 1999 are due to human activities in the forested areas that affect river flows. Between 2010 and 2017, the flows rise to higher levels compared to previous years and afterwards there is a declining trend. This is attributed to interventions aimed at restoring Eastern Mau which normalized flows.

Figure 4.8 shows the mean monthly river flows from 1979 to 2020. The mean monthly river flows for each year was used to further understand how the flows in River Njoro have changed per month. An interval of 10 years was used to determine changes that have taken place over time during the rainy seasons. In Eastern Mau, the long rains are from March to May with short rains between July and September. There was a gradual increase in river flows during the long rains from 1979 to 2020 with an exception of 1999. 2020 recorded the highest river flows in April with the lowest in 1999. There was a gradual decline in flows during the short rains from 1979 to 2009 with 2020 recording the highest and 2009 the lowest in September.

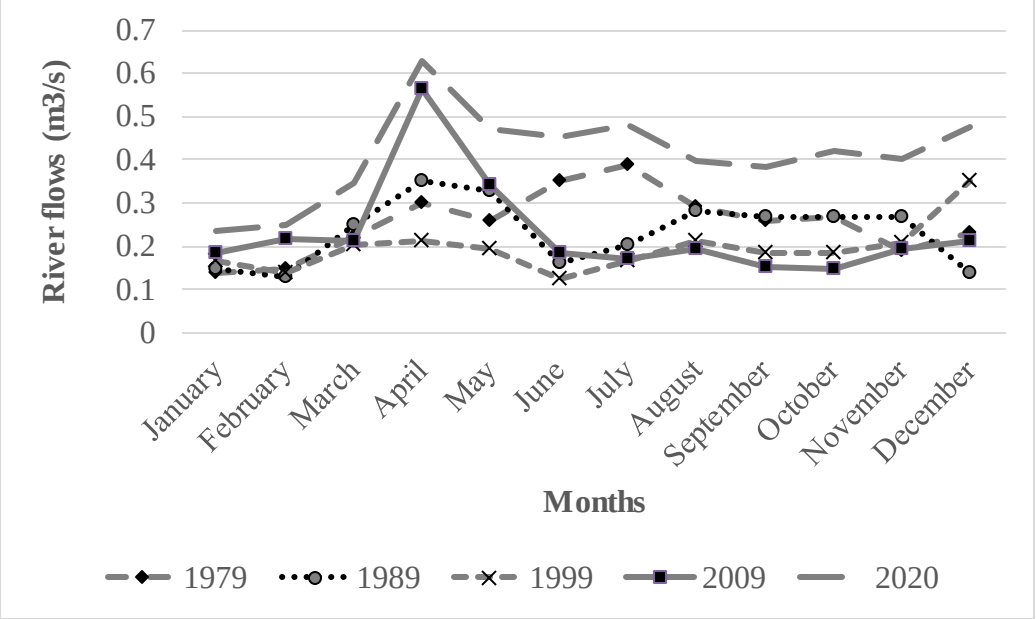

Figure 4.8 Monthly river flows of River Njoro

There have been changes in river flows during the long and shorts rain. The shift in river flows over the different months is attributed to the decrease in short rains and increase in long rains due to deforestation in the area. The river flows have increased during the long rains and decreased during the short rains. The monthly river flows have fluctuated the most during the peak and low rainfall seasons.

4.4.2 Impact of Settlement Schemes on Streams, Rivers and Wetlands

Eastern Mau Forest Reserve acts as a major watershed owing to the several rivers and streams which feed into water bodies as shown in Table 4.3 and Figure 4.9. Settlement of people in the forest reserve was based on the Forest Act which aimed at reservation, protection and control of forests by the government (RoK, 1982). The presence of human activities within the forest reserve threaten the existence of streams and rivers (Kibuba & Jenkins, 2005). Humans rely on rivers for different resources, however, the lack of conservation programs and awareness greatly affect the catchment areas (Anthony, 2018). The area under forest cover has decreased immensely and as people head towards the higher points, destruction of tributaries is imminent without conservation programs.

Eastern Mau Forest Reserve was gazetted in 1954 under the 1942 Forest Act Cap 385 which was later revised in 1982 and 1992. The gazettement of Eastern Mau as a forest reserve was legal and procedural with an aim of management of the forest area. Section 4 of the Act provided for alteration of forest boundaries and de-gazettement of forest areas by the Minister (RoK, 1982). It also authorized creation of nature reserves within the forested areas by the Minister and expulsion of forest squatters with no regard of their existence in the forest.

Eastern Mau is a fertile area which favours agriculture and growth of forests. The people who were settled in the schemes maximized on the opportunity to grow crops and rear livestock. The changes in the reserve have also been brought about by the commercialization of tree products especially for timber. Tree logging and charcoal harvesting is a common phenomenon in Baraget Scheme (RoK, 2018). The lack of proper enforcement of the law and forest management regulations in the area encourages further deforestation and degradation of the reserve. The first groups of people to settle in the forested area were elated at how rich the soils in the reserve were (Kimaiyo, 2004). As news of fertile land spread around, more people wanted a share, leading to migration of new people into the reserve. People who had earlier been allocated land sold their parcels and moved to other areas. There are people from surrounding regions who sold their land in favour of cheap, fertile land in the reserve. This led to an influx of people into the area hence subdivision of land, encroachment and degradation (Kweyu *et al.*, 2019).

Figure 4.9 shows farmlands, rivers and tributaries within the forest reserve. The figure indicates that some rivers and streams are emanating from the settlement areas while others are deeply into the forest. Some of the tributaries and streams have their sources in what is currently farmlands, inside the forested area and outside Eastern Mau. . During demarcation, no land was set aside for riparian zones and conservation of wetlands (Kweyu *et al.*, 2019). Most tributaries are found within the forested area hence the need to preserve the riparian areas from further destruction.

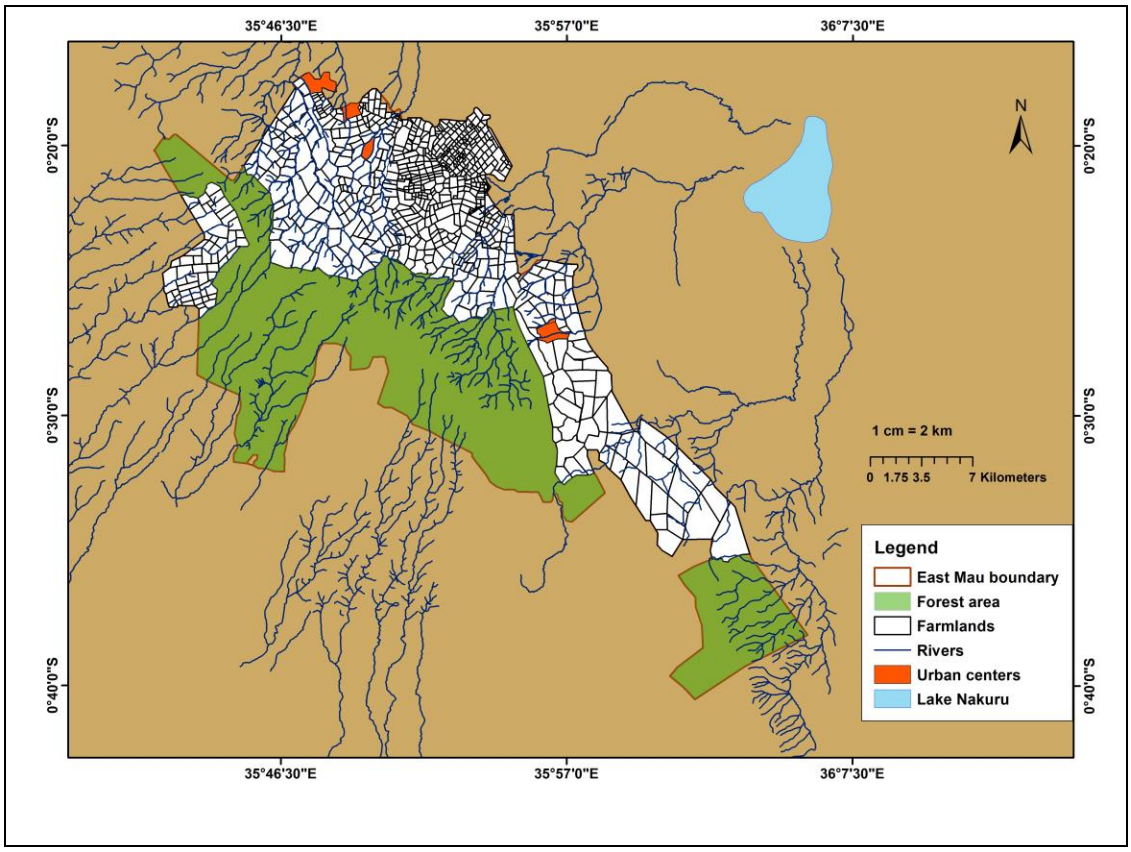

Figure 4.9: Farmlands and Rivers in Eastern Mau Forest Reserve

The Forest Act did not anticipate threats to resources from human activities hence lack of integrated planning in the process. The settlement of people in forested areas did not take into consideration the need for planning of the watershed, water points, intakes, water tanks and preservation of wetlands in the 1980s. In addition, the move to settle people was politically motivated with the directive put into place without consideration of the importance of the reserve as a watershed. Ecologically sensitive areas of the watershed were given to people during allocation of land (Klopp, 2012).

Settlements on watershed areas affect the existing natural resources. This requires conservation programs such as riparian, water and soil conservation. As people were settled in the schemes in the 1980s and 2001, there were no conservation schemes in place. There were no extension education activities to deter agricultural activities from affecting the existing water resources including tree planting, terracing and soil conservation activities (Mainuri, 2018).

The settlement of people within the forested areas have led to drying of streams, springs, rivers and wetlands with other sources becoming seasonal. In the Njoro area for instance, 13 streams out of 32 have dried up over the last 40 years including Mumberes whereas Larmudiak rivers, Umani Spring and Napuiyapui Swamp have turned seasonal. Table 4.3 shows some of the existing, seasonal and dried up rivers and streams flowing from Eastern Mau. Most of the streams that have dried up are found outside what is currently the forested area (Nyawira, Mwangi, & Cheruiyot, 2019). As people continue to settle and farm upstream near the forested area, the downstream areas are affected immensely due to siltation, which compromises river flows. Human settlements have therefore affected river flows.

Table 4.3 Existing and dried up rivers and streams in Eastern Mau

Rivers		**Streams**		**Wetlands**	
Existing	Dried up	Existing	Dried up	Existing	Seasonal
Njoro Molo Naishi Makalia Enderit	Mumberes	Elburgon Rongai Enkare Mau Kiptunga, Nessuit, Ndarugu, Shuru, Ngosur, Kibunja, Waiseges, Langs, Kihingo, Kisonei, Entiyani, Olorropi, Daraja-mbili, Tuiyopei, Kipsinende	Isirkon, Enchorro, Kaplekwa, Munji, Chepkutbei, Sugutek, Kiboso Lelechwet, Chepkitach, Kapseita, Chepakundi, Lengape,	Maji-moto Nguso	Napuiyapui swamp Umani Larmudiak

(Adapted from KWTA, 2017)

People who have settled in the upstream areas continue to plant tree species such as eucalyptus along the rivers and streams. The trees are meant for commercial purposes owing to their high demand and short maturation period. This leads to drying up of some rivers as others become seasonal. Eucalyptus take a lot of water and nutrients which leads to soil exhaustion and decreased growth of other crops. There are regulations and laws which ban the growth of eucalyptus along rivers, however, poor enforcement encourages people to plant eucalyptus along banned areas (Anthony, 2018). The changes in land use from forest to farmland leaves the soil bare, leading to erosion. Agricultural methods which leads to soil erosion, intensive agricultural activities such as mechanization, loss of vegetation cover and overgrazing makes the top soil loose. An increase in amount of precipitation and poor agricultural methods accelerates the rate at which soil is eroded (Newson, 2012).

4.4.3 Impact of Human Settlements on River Flows

Monthly river flows are affected by the kind of anthropogenic activities taking place around a stream. Land preparation for planting in the forest reserve mostly takes place in January and February when the rainfall levels are low. As the rains set in and planting begins, the soil is bare, with less vegetation growing. This leads to immense soil erosion as there is nothing to hold the soil in place. Harvesting takes place during the low rainfall seasons leading to less siltation as there is vegetation on the land. Figure 4.10 shows the correlation between area under farmlands and river flows. There is a positive correlation between farmlands and river flow data between 1989 and 2020. An increase in farmlands leads to an increase in river flows and versa. There was a negative correlation in 1979 since there were minimal farming areas in the reserve.

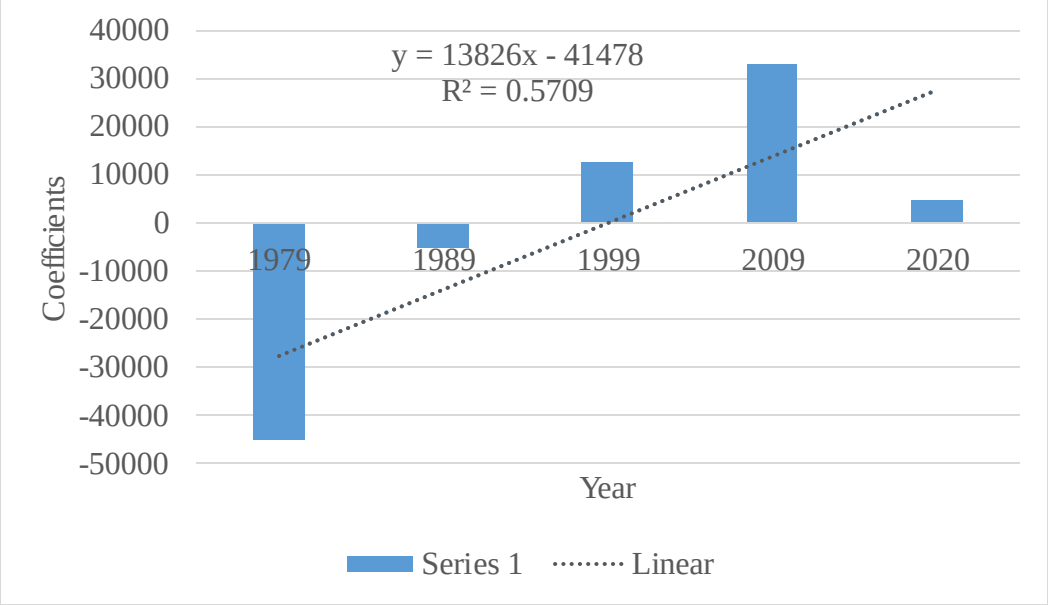

Figure 4.10 Correlation between farmlands and river flows in Eastern Mau

There have been substantial changes in river flows over the years. The increase in river flows is an indication of increase in surface run-off from each rainfall event in the area. Increase in surface run-off results from less infiltration and interception of water from decrease in forest cover, tree plantations and increase in farmlands. The decrease in forest cover leads to an increase in total volume of flow due to reduction in evapotranspiration and decreased interception of rainfall (Mainuri, 2018). As more people continue to settle in the forest area, they engage in activities which support their livelihoods like agriculture. The demand for water and forest resources such as wood and charcoal increases, leading to destruction of the watershed. The continuous ripping of vegetated areas leaves the land bare and without vegetation to hold soil in place. The result is increased surface run-off hence sedimentation in the rivers.

The results are similar to those obtained by Yaowen and Chansheng (2017); in their study, there was a decline in monthly river flows over the years, attributed to deforestation and increased water use as a result of human settlements. The decrease in vegetation cover leads to increase in annual discharges, surface run-off and peak flows whereas low flows decrease. There is also less infiltration of water which is responsible for revitalizing the streams. The high peaks will only last when there are high rainfall levels and as the rainfall levels decrease, flows decrease even in springs. The alteration

of water bodies at the upstream level affects the whole watershed system (Masuma & Adullah, 2020). In Eastern Mau, as people ventured further into the encroached areas, they further impacted the catchment. This indicates that the reserve has experienced changes which have greatly affected river flows. Settlement of people close to watersheds has an impact on ecosystems and biodiversity. Sometimes, humans can have a positive impact on ecosystems, but often human actions can have detrimental ecological consequences (Tomas, Andrzej, & Agnieszka, 2019). Some of the human activities that lead to disturbances in watersheds include dumping or discarding materials into water bodies especially chemicals that flow into rivers once it rains.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

The first objective was to examine land use land cover changes in Eastern Mau Forest Reserve. The findings reveal that there have been significant land-use land-cover changes in Eastern Mau from 1979 to 2020. The forested areas declined by 42.7% while area under farmland increased by 41%. There is an inverse relationship between forest areas and farmlands as a decline in forest area leads to an increase in farmlands and vice versa. There have been land transitions from forested areas with dense vegetation to farmlands. There have been numerous efforts towards restoration of Eastern Mau by various institutions leading to an increase in forest areas and decline in farmlands.

The second objective was to examine settlement schemes and boundaries in Eastern Mau Forest Reserve between 1979 and 2020. The findings show that people have encroached beyond the boundaries of settlement schemes when they were established. The settlement schemes were established without the alteration of boundaries, leading to encroachments over time. In a bid to restore the watershed, interventions including evictions have been carried out over time, at times with little success. There is a proposed boundary meant to demarcate the areas for conservation and settlement.

The third objective was to assess the impact of settlement schemes on river flows in Eastern Mau Forest Reserve from 1979-2020. The findings indicate that settlement schemes have led to some rivers, streams and wetlands drying up. There is a direct relationship between farmlands and river flows as an increase in acreage under farmlands leads to increase in river flows and vice versa. Settlements schemes lead to a decrease in forested areas that result to an increase in surface run-off.

5.2 Conclusion

Eastern Mau Forest Reserve is a watershed that a number of has rivers, streams and wetlands emanate from inside the forested area, inside established settlement schemes and outside the former forest reserve. Settlement schemes have led to land use changes in Eastern Mau as a result of conversion from forest to farmlands. There is an inverse proportion between farmlands and forests where a decrease in forests leads to an increase in farmlands and vice versa. There is a relationship between river flows and

farmlands as an increase in area under farmlands leads to an increase in river flows. Settlements affect land cover that in turn affects forests and impacts capacity of land to absorb rainfall water, which leads to higher runoff and subsequently higher flows. Settlement schemes led to changes in river flows over the years due to land use changes as people slashed vegetation for agricultural activities that led to soil erosion and siltation. Settlement schemes in Eastern Mau forest reserve have led to land use and land cover changes. The encroachment of people beyond the forest boundary has led to agricultural activities which have affected flow of rivers.

5.3 Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. National Environment Management Authority (NEMA) in conjunction with National Land Commission should establish permanent riparian zones within the forest reserve to prevent further encroachments
2. The government should establish and implement programs that will conserve water and land resources in the reserve.
3. The government needs to come up with practical strategies and plans to get people out of the forest and ensure their safe transition to other places.

5.4 Areas for Further Research

The following recommendations are made for further research:

- Impact of land use changes on underground water resources of Mau Complex.
- The impact of land use changes on the stream flow using hydrological models for future scenarios.

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APPENDICES

Appendix 1: Interview Schedule

I am a Kenyatta University student pursuing Masters in Environmental Planning and Management. I am carrying out a research on "Settlement Schemes and their Implications on Eastern Mau Watershed, Nakuru County, Kenya." I am kindly requesting for some information from you. The information you will provide shall be used for academic purpose only.

1. What is the status and percentage of forest cover in Eastern Mau forest reserve as at present?
2. During the last four decades, how has the forest cover changed in acreage & percentage?
3. What are the drivers of forest cover change in the area?
4. What are the impacts of human settlements on protection of the reserve?
5. Which measures have you put in place to protect Eastern Mau forest reserve?
6. Are there existing policies on protection of the reserve?
7. How have you promoted reforestation in the area?
8. How have you dealt with deforestation and related human activities in the area?
9. How can we better manage the reserve in the future?

Note: Please would you kindly provide me with any written reports, that is.

- Strategic Forest Management Plan
- Strategic Environmental Plan
- Any other report relevant to the study