IMPACTS OF LAND USE AND LAND COVER CHANGES ON CHEPKAITIT AND MOIBEN RIVERS' WATERSHED ALONG TRANS NZOIA, UASIN GISHU AND ELGEYO MARAKWET COUNTIES, KENYA

BY

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DECLARATION

DECLARATION BY THE STUDENT

This thesis is my original work and has not been presented to any other institution for any academic award.

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DEDICATION

I wish to dedicate this work to my father Daudi Chepkwony and grandfather Musa Ngelechei for their tireless support in my studies. I dedicate this work also to my sisters, brothers, husband and my children for their moral support.

ABSTRACT

River water sources in Kenya are facing challenges arising from a number of factors including watershed degradation. The major causes of watershed degradation are extensive deforestation and poor soil and water conservation measures. River flow discharge is influenced by LULC changes, soil and water conservation measures and managerial practices applied by farmers and further compounded by the growing human population. This study was conducted in Chepkaitit and Moiben Rivers' watershed located along Trans Nzoia, Uasin Gishu and Elgeyo-Marakwet countiesin Kenya. The specific objectives were to establish LULC changes in the years1980, 2000 and 2020; so as to determine how change in LULC types influences river flow and to analyze the kindsand level of soil and water conservation measures applied by residents. The common property Theory was used to guide the study. The study used descriptive and correlational research designand the data was both primary and secondary. The target population under study was 96,746 household heads and a sample size of 383 household heads was used to fill in the paperless questionnaires developed and deployed in the kobo toolbox. Stratified random sampling techniquewas employed for the survey and the cleaned data was analyzed using SPSS software. The LULC change analysis used data from Landsat satellite imagery downloaded from United States Geological Survey website while the Soil and Water Assessment Tool model was used to quantify the impacts of river discharge variability under base scenario (1980 LULC), scenario 2 (100% agriculture LULC) and scenario 3 (100% Forest). The SWAT model used weather data downloaded from the "Global Weather data for SWAT" website and DEM (slope data) downloaded from USGS website while model output calibration used SWAT-CUP. The study found out that there were great changes on LULC on the study area within the period of study. The natural forest, bush land and wetland had reduced by 13%, 95% and 67% respectively while cropland and plantation forest had increased by 69% and 32% respectively. The study also found out that changes in the LULC types significantly influenced the river discharge with R^2 of 0.89 at $p= 0.00001$ with a significant level of 0.05. The change in river discharge was more pronounced in April where scenario 2 river discharge varied by -28.51% and 19.57% for scenario 3. The research further established the soil and water conservation measures as contours, gabions, minimum tillage, tree planting and strip cropping. The study concluded that there were significant changes in LULC types in the study periods, the LULC changes influence on river discharge was significant with synchronized flow under forest cover and all farmers were applying some form of water and soil conservation measures in their farms. The study recommends that afforestation be prioritized especially in the steep slopes, while the riparian vegetation should be conserved as required by the policy guidelines and farmers to be encouraged to practice conservation agriculture.

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ACRONYMSAND ABBREVIATIONS

DEM: Digital Elevation Model

ET: Evapotranspiration

FAO: Food and Agricultural organization.

GIS: Geographical Information Systems

GWP: Global Water Partnership

HRU: hydrologic response units

LULC: Land Use Land Cover

LULCCs: Land Use Land Cover changes

PPU: Percent prediction uncertainty

R^2: Coefficient of determination

SPSS: Statistical package for social scientists

SUFI-2: Sequential Uncertainty fitting version 2

SWAT: Soil Water Assessment Tool

SWAT- CUP: Soil and Water assessment tool Calibration and Uncertainty Program.

SWCM: Soil and water conservation and management

SWRRP: Simulator for water Resources in Rural Basins model

UNEP: United Nations Environmental Programme

USGS: United States Geological Survey

UTM: Universal Transverse Mercator

VIC: Variable Infiltration Capacity

WEAP: Water Evaluation and Planning Model

WGS: World Geodetic Survey

DEFINITION OF TERMS

ArcSWAT: Refers to integrated SWAT in geographical information systems- ArcGIS

Degradation: Refers to the process by which Chepkaitit and Moiben Rivers' watershed quality is made worstby land use and land cover changes.

High flow: It is the flow of high levels of water in Chepkaitit and Moiben Rivers' watershed.

Land Cover- In this study it refers to the earth surface components of land that are Physically visible in the study area which includes forests, bush land and wetland mainly.

Land Use: The human modification of Earth's terrestrial surface, which in the study area includes agricultural and settlement**.**

Low flow: It is the flow of low levels of water in Chepkaitit and Moiben Rivers' watershed during prolonged dry weather

Soil erosion- It refers to the wearing a way of a field's topsoil by the natural physical forces of water or through forces associated with farming activities such as tillage and settlement in Chepkaitit andMoiben Rivers' watershed.

Surface run off. The excess rain water that flows on the surface of the earth after the rain.

River discharge/ stream-flow: The volume of water flowing in a cross-section of Chepkaitit and Moiben Rivers' watershed overa set period of time. It is usually measured in cubic meter per second (m^3/s).

Watershed: This refers to the entire area of Cherangany and mt. Elgon that drains water into Chepkaitit andMoiben Rivers' watershed.

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CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

The increasing population size and consequential increase of human activities have led to abuse ofnatural resources in a way that some of the rivers no longer reach the lake and the sea due to loss in river basins (GWP, 2004). The pressing problem of human land use is greatly affecting resourcemanagers and land users in balancing between human needs and the environmental justice (De Fries *et al*., 2007). Wang *et al* (2016) in a study in China, Canada and Europe mentions that watershed management is an ever-evolving practice that involves management of land, water, biota and other resources in a defined area for ecological, social and economic purposes. They argue that though there is progress in watershed management strategies and there are stillnumerous issues that affect the success of their management. Li (2009) argues that there is an ever -increasing rate of human advancements in watersheds giving rise to changes globally on climate conditions and forms of land use in catchments. The effects of these changes on the environment and ecology are receiving extensive attention (Vorosmarty *et al.*, 2000). The great issue of destroying forests and changing them to agricultural, urban and residential lands is seen to be increasing in several parts of the world and it is greatly influencing environmental modifications (Olang, 2009). The most significant changes in land use are related to agricultural expansions that result in deforestation (Githui *et al.*, 2010). It has been put forth that loss of forests has contributed to flooding in several regions of the world, for instance, Abramovitz of World Watch observed that Yangtze huge flood of 1998 in China was in part caused by deforestation (Csongos, 1998). Twesigye *et al.,* (2011), also in a study in part of the Nzoia River argue that deforestation and encroachment into forests has resulted in severe erosion. Additionally, Githui, (2021) postulates that erosion in the upper catchment and flooding in the lower catchment has been attributed largely to deforestation. Bruneau (2005) in his study also adds to the fact that the major cause of increased flooding, soil degradation and decreased discharge of aquifers is due to loss of forest cover around the watersheds. Increased deforestation to create room for agriculture and decreased recharge to aquifers due to intensified agricultural activities may eventually lead to change of climate in the region over time. It is also attributed that land use activities have altered a proportion of the planet's land surface and thus affecting the structure and functioning of the ecosystems (De-Fries *et al*, 2007). According to Kilonzo 2013, intensification of farming in the water catchments led to increased soil erosion and thus affecting water retention capabilities.

The livelihood of East Africa depends majorly on agriculture and therefore, in order to meet the demand for land, natural forests have been substituted with human settlement, urban centers, farmlands and grazing land (Maitima *et al.,* 2009). Loss of indigenous forests on streams that were originally in forested catchments and their subsequent conversion to agricultural use (for example in East Africa) is one of the major threats to surface water quality (FAO, 2010). Major water catchment areas in Kenya have lost their forest cover over time (World Bank, 2007). Deforestation is responsible for about 25% of net annual releases of carbon dioxide into the atmosphere and it also reduces the capacity of forests to absorb greenhouse gas emissions (Aloo, 2004). Deforestation according to Bonan *et al*., (2004), changes the hydrological, geomorphological and biochemical states of streams. Anthropogenic changes in vegetation generally results in increased discharge because root density and depth have been reduced by agricultural activities (Canadell *et al.,* 1996). Additionally, a reduction in dry season flow is often cited as a consequence of deforestation (Liu *et al.,* 2015). There is a common argument that forests act both as 'pumps' through enhanced evapotranspiration (ET) rates and as 'sponges' through increased infiltration rates and soil moisture retention (Bruijnzeel, 2004; Arancibia, 2013). Forested watersheds therefore exhibit smaller streamflow rates than watersheds dominated by other managed land uses during and after a rainfall event. Forest cover loss results in changes in albedo, reduction in aerodynamic roughness, reduction of leaf area, and reduction in rooting depth, consequently causing a reduction in evapotranspiration (ET) which subsequently affects stream-flow (Costa *et al.*, 2003; Farley *et al.,* 2005).

Odira *et al.,* (2010) and Githui (2021) in their studies on Nzoia River concluded that deforestation in the catchment region affects stream flow in that during the rainy season, stream flow rate increases compared to when there is forest cover. In a study by Mwetu, (2019), in Njoro River in Kenya, it was also observed that with increased reduction in land cover in the river upper catchment, there was a reduced average annual discharge.

However, this is not conclusive since there is still a debate in looking at the complex relationship between forest and water resources (Ellison *et al*., 2012, Lacombe *et al.,* 2016, Filoso *et al*., 2017). Therefore, there was a need to assess how loss of forests, for other land uses, has impacted on Moiben and Chepkaitit rivers' watershed. Furthermore, changes in land use and land cover (LULC) have brought some concern globally as they impact not only in the water quantity but alsoin the quality of water and soil. Conservation of soil and water resources is most critical in developing countries where populations utilize marginal lands for their subsistence. It has been put forth that clearing of natural vegetation or forests in the field exposes the topsoil to severe erosion (Onywere, 2005). On the other hand, increased erosion as a result of increased deforestation and agricultural activities on the upper part of the river in a study on Njoro River hasled to sedimentation and siltation in the river (Mainuri *et al*, 2014). Mango *et al* (2011), argue thatland use and management practices affect processes in a river basin such as erosion, surface runoff, recharge and evapotranspiration. They attribute poor management of soils, overgrazing, deforestation and settlements in river basins to degradation of river Mara. China *et al.*, (2017), in a study in Isiukhu catchment along river Nzoia, recommended that indiscriminate felling of trees,mono-cropping, over grazing, ploughing up and down the slope and other human activities that expose ground surface for high surface run-off should be discouraged.

Therefore, because LULC activities impact on the soil and water directly, there was a need to lookat the changes in the river flow and extent to which water and soil conservation measures have been applied in the Chepkaitit and Moiben rivers watershed. Numerous hydrological study modelssuch as Soil and Water Assessment Tool (SWAT), Simulator for Water Resources in Rural Basinsmodel (SWRRB), Water Evaluation and Planning Model (WEAP) and Variable InfiltrationCapacity (VIC) model have been used to establish river discharge response to LULC changes. Thisstudy used SWAT Model since the stream flow variability can be modeled based on slope, LULC, precipitation and soil data. SWAT modeling tool has been seen to be an effective tool that can be useful in assessing water resources in a wide range of scales and differing environmental conditions all over the world (Arnold *et al*., 2006). Narayanan (2012) uses this tool to model the river basin of Arroyo Colorado in South Texas and found out the water quality as deteriorating. Additionally, this modeling tool was used by Odira *et al*., (2010) in River Nzoia in Kenya to analyze the impact of LULC on river flow volumes.

In the analysis of LULC, Remote Sensing and Geographic Information Systems (GIS) tools havebeen very essential because they can map the real ground from images or mere pictures. For instance, it was used by Shekhar, (2013) in his study on LULC change in a watershed in British Columbia and it was detected that there was a reduction in wetland trend of the region due to expanding natural gas development and agricultural activities. These tools were also applied by Ngeno (2016), in Nyangores River in Kenya to determine the changes on the LULC and he realized that the natural forest land had reduced.

1.2 Statement of the Problem

The study was done in the upper reaches of the river watershed covering Chepkaitit and Moiben. These rivers' watershed has natural forest cover, which is under pressure from increasing human activities. It is predisposed to land degradation associated with deforestation, overgrazing, poor agricultural practices, soil erosion and deteriorating riparian vegetation. Deforestation for expansion of agriculture and urbanization are degrading Moiben and Chepkaitit Rivers' basin conditions and increased surface run-off is prevalent in most deforested parts of the basin since it has hill slopes and annual crop farming, increasing its vulnerability to soil erosion. Since Kilonzo, (2013) mentions that removal of forest, farming and other land uses negatively impacts on the hydrology of a river basin, thus intensification of mechanized farming in Moiben and Chepkaitit watershed may then affect the water retention capabilities of the watershed and therefore lead to excessive run off into the rivers. This study therefore will establish the status of LULC change in Chepkaitit and Moiben Rivers, the influence of LULC change on river flow and establish types of soil and water conservation measures applied by the residents to aid in informed decision so as to analyze the most appropriate conservation measures to avoid the problems associated with non- conservation.

1.3 Objectives

The main objective of this study was to analyze the impacts of land use and land cover changes on Chepkaitit and Moiben Rivers' watershed.

The study was guided by the following specific objectives;

1. To analyze land use and land cover changes in 1980, 2000 and 2020 in Moiben and Chepkaitit rivers' watershed.
2. To model the influence of LULC changes on rivers Chepkaitit and Moiben waterdischarge.
3. To establish the types of water and soil conservation measures in Moiben and Chepkaitit rivers' watershed.

1.4 Research Questions

This study was guided by the following research questions:

1. How has LULC changed in1980, 2000 and 2020 on Moiben and Chepkaitit rivers watershed?
2. What is the influence of LULC change on Chepkaitit and Moiben rivers' discharge?
3. What are the main soil and water conservation measures applied in Chepkaitit and Moiben rivers' watershed?

1.5 Hypothesis

To analyze the soil and water conservation measures in the study, a hypothesis was developed to analyze the extent of soil erosion and the nature of slope on the area. The hypotheses used for thestudy were;

H1: there is a significant relationship between the nature of the land and the extent of soil erosion

H0: there is no significant relationship between the slope of the land and the extent of soilerosion;

1.6 Justification of the study

Moiben and Chepkaitit Rivers' watershed in Kenya, is a basin that has a great population depending on it almost entirely. Agriculture, particularly crop farming and livestock grazing, is the major economic activity of many people living in this region. Therefore, the ever-increasing population clears the forest to pave way for agriculture. Much of this forest is found in the upper catchment of the Chepkaitit and Moiben rivers' watershed.

This is likely to cause changes in the land use and land cover through clearing of natural forest to introduce agriculture in the area. Thesechanges then in the watershed are likely to affect the rate of flow of the river basin during the dryand rainy seasons. Thus, the volume of water in the rivers is most likely to be affected by increasedland use land cover changes in the region. This study then is meant to analyze the changes in the land use land cover types in the region so as to provide information for use in managing changes in the river discharge that have been noted in the Watershed.

1.7 Scope of the Study

The study was done in Moiben and Chepkaitit rivers' watershed located between the coordinates $35^0$20'01.5''- $35^0$07'57.6''E and $1^0$02'18.1''- $0^0$55'06.9'' N (WGS 84). The study looked at the

LULC types and analyzed changes from 1980, 2000 and 2020 using remotely sensed imagery. Landsat images were preferred for use in this study. The study also modeled the influence of LULC changes on river discharge using SWAT, from the base scenario of year 1979 to 2013. Moreover, the soil and water conservation measures applied in the study area were established and documented. The study was limited to the following parameters: LULC change with time,modeling the influence of LULC on river discharge and establishing the soil and water conservation measures.

1.8 Significance of the Study

Due to increasing changes in land use and land cover mainly by human-induced activities, detection and quantification of land use and land cover dynamics through the integration of remote sensing and Geographic Information Systems (GIS) is inevitable for ensuring sound watershed management. Planners need to understand how land use change influences the catchment hydrology so as to formulate policies that minimize undesirable effects of future land use changes. The study will inform academicians and other researchers on how LULC changes are likely to impact on discharge rate and volume in different seasons. They can use this work in future to reference their study. The results of the study will also contribute to Kenya's vision 2030dream, which aims at secure, clean and sustainable environment, through curbing of misuse of water towers to sustainably manage water resources.

The outcomes of this study are intended to inform watershed managers on ways to reduce soil erosion rates, for example, value of integrated conservation practices, curbing unregulated land use, overgrazing and deforestation as well as encouraging conservation tillage. The findings will further help policy makers plan for sustainable soil management strategies as the country gears towards achieving land degradation-neutrality. Additionally, the study informs on non-conformity to the various environmental policies and law in place. For example, the Land Act-Cap 307, section 13-revised in 2010- (which states that the riparian zone, including vegetation which grows along the river is the government property) may have been abused extensively by the people living along these rivers.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature on watershed overview, land use and land cover and its impacts onriver discharge, SWAT Model, Landsat imagery and GIS. This chapter majorly made use of journals, books and relevant publications. The purpose of this chapter is to get clarity of what has been done in other areas by other scholars or researchers on the related subject so as to have a clearknowledge gap for this study.

2.1 Overview of Land Use and Land Cover

Land Use and Land Cover (LULC) is a very wide aspect that signify the interaction between natural and human influence on the Earth's surface and when linked with water resources, LULC changes impacts has been linked to groundwater, stream water, surface runoff, evapotranspiration, sediments and nutrient yields (Steffen *et al*., 2006; Lambin *et al*., 2006).People majorly confuse and interchangeably use Land use and land cover because of the complexity that exist between them. For instance, grassland land cover may support land uses types such as livestock farming, cropland and grassland (Haines-Young, 2009). Despite the confusion however, Land use and land cover are two different terms; Land cover is a representation of bio-physical attributes of the earth's terrestrial surface and immediate sub-surface including biota, soil, topography and built-up structures, while land use is the aims for which attributes of land cover have been modified (Lambin *et al*., 2006). According to Ravisankar (2017), land cover is defined as what covers the earth's surface on a given ground area, for example, bare soil, grassland bush land, water, forest among others. Knowing the land cover provides the basis for monitoring. Land use on the other hand, is actually referred to as what service the land provides, for example, wild life habitat, agriculture, urban and recreation. And this is important as it will be the basis for laying strategies to balance conservation, conflicting uses and developmental pressures. Land use and land cover change can alter biodiversity, soil quality, runoff quality, sediment transportation and other attributes that are associated with the terrestrial landscape (Steffen *et al*., 2006). Timely and accurate detection of land use and land cover changes provides a clearer understanding of the interactions and relationships between the natural environment and the activities of man, so that the decision makers will get up to date information about land use to make better management of future development (Bakr, et al., 2010). Agrawal *et al*., 2002, provided models of land use and land cover and the models incorporate three critical dimensions (time, space and human decision making) and to distinct attributes (scale and complexity) for each dimension. In land use land cover monitoring to assess the changes, one should know that there is modification when the changes are within classes of land cover, or otherwise, there can be conversion when there is change occurring between classes of land cover (Giri 2012). The understanding of the reasons and trend of land use and land cover change has improved the methodologies to monitor and analyze the LULC changes (Lambin, et al., 2003). Improved understandings of the dynamic changes of land uses and land covers will enable more valuable and reliable progress to analyze the modification of land resource on the earth's surface. Additionally, improved knowledge of land use and land cover changes provides an understanding of impact from human activities. Xu et al. (2000) argues that land use is the social and economic attributes of the land and the land cover means the naturalattribute and physical characteristic of the land. The spatial area of land cover is gradually varied, and the change of the time of land cover has an obvious aspect change; the changes of land use arenot related to the season, the change of spatial area has a clearly edge due to the changes of land use are absolute dependent on man activity (Xu, et al., 2000).

Human being have altered the environment for years to satisfy their basic needs and the impact ofhuman activities on the land has grown greatly, altering entire landscapes, and ultimately impacting the nutrient and hydrological cycles of the earth and also leading to changes in the climate. Significant population increase, migration, and accelerated socio-economic activities haveincreased these environmental changes over the last several years (Sonneveld, 2002; Zelalem, 2007). The growth of Population can push the rural poor into marginal lands (Tsegaye, 2007).

Land use and land cover are seen to be the most prominent forms of global change in the environment as they occur at temporal and spatial scales (CCSP, 2003). The changes in the land use and land cover are quantitative in an area and are the manifestation of the anthropogenic and environmental driven forces (Liu *et al.*, 2009). Human activities are immensely touching on morenatural areas and this have greatly led to modification in the land use and land cover and this will later have serious implications on the ecological sustainability and on the climate change (Roy andRoy, 2010).

The drivers to LULC changes have been classified into direct causes and indirect causes (Lambin*et al*., 2001). The authors further noted that direct causes, which are also named proximate causes, have been attributed to anthropogenic activities that directly cause the modification of the land cover such as agriculture or settlement, while the indirect causes compensate the underlying drivers that trigger the direct drivers such as demography and policies. Land use change may be gradual or abrupt due to specific events such as natural hazards or change in political forces (Kariyeva and VanLeeuwen, 2012). Anthropogenic activities, such as farming, deforestation and expansion of urban areas taking place within many watersheds greatly affect the status of wetlandsas much of the runoff drains directly into these water bodies and this can lead to increased levels of sedimentation and pollution of water bodies due to the reduction in wetland buffer zones (Kipkorir, 2017).Forests are seen to have great importance on watershed as they influence the rateof infiltration, which may decrease catchment runoff (Zhang *et al*., 2014). However, deforestation has resulted due to various human activities such as need for timber, firewood, settlement and agriculture such that half of Kenya’s fresh water is used for irrigation agriculture (Beyene, 2015). A study by Ololade *et al*., 2008 on land use land cover mapping and change detection in a period of three decades, the grassland and woodland had been replaced by agricultural/ cropland. These activities on watersheds cause threats such as sedimentation, pollution, climate change, deforestation, landscape changes and urban growth (Nel, *et al*., 2009; Cai, 2016). A report to Africa Science News (http://africasciencenews) says that human activities such as encroachment to wetlands, deforestation and other poor land-use practices have led to environmental degradation and these activities eventually have resulted to soil erosion leading to siltation of water bodies andthus increased discharge in several parts of East Africa (Nuttal, 2006). He further states that forestsare very important in building resilience of the natural ecosystem.

Another land use activity that is important in this study is mining and sand harvesting. In a study by Akali *et al*., (2015), in Nzoia River, it showed that there was excessive in-stream sand harvesting that led to channel instability, destruction of riparian vegetation and aquatic habitat andlowering of water tables near riverbeds. This land use practice may then impact on the quantity and quality of water in the river. Biswajit (2011) in his study as well as in his research found out that the changes in the land use and land cover is caused by mining, where an increase in mining activities leads to clearing of vegetation in the area.

2.2 Land use Land Cover (LULC) Changes in a Watershed

LULC changes analysis technique has been very important in management of land and natural resources research. It has been put forth that proper planning and utilization of natural resources plus their management require information on changes in LULC types (Mallupattu *et al.*, 2013). Therefore, in order to understand and assess the environmental effects of such changes, precise and up to date data on land cover change is very important (Giri *et al*., 2005). Additionally, different land use classes are used to detect variation of changes in order to get reliable and up-to date information on temporal and spatial change (Lilian, 2019). Land cover change denotes modification in particular continuous characteristics of the land such as vegetation type, soil properties, while land-use change is modification in the way certain area of land is being used or managed by men (Patel et al., 2019). The changes in LULC are responsible for a number of local and global impacts, including biodiversity loss, human health effects and the loss of habitat and ecosystem services (Patel et al., 2019). Land use planners, resource managers, and conservation officers can utilize predicted land use and land cover changes to encourage sustainable management in land and mitigate adverse effects. LULC change detection and prediction have become essential considerations in a wide array of disciplines, such as identifying biodiversity hotspots for prioritizing conservation efforts, modeling rural and urban planning (Theobald and Hobbs, 1998; Pocewicz, *et al*, 2008), and investigating degradation processes, among others (Lamchin, 2018).

Evidently, LULC changes have been observed in many rivers' watershed studies. For example, a study conducted by Mhangara (2011) in Keiskamma catchment in South Africa reveals that land use change has been experienced. Akali (2015) in a study to analyze LULC changes in river Nzoia found out that between 1990, 2000 and 2010, the cropland and grassland increased while forestland reduced. The water body and the wetland were said to have also decreased. Githui *et al*., (2010) and Odira *et al*., 2010, also hold the same sentiments that the basin has experienced various land use dynamics between 1990 and 2010, in their studies along river Nzoia. They mentioned that themajor changes were observed in forest and cropland. Maitima *et al*., (2009) in a study in Eastern Africa region notes that land use changes have transformed from land cover to farmlands, grazing lands, human settlements and urban centers at the expense of natural vegetation.

Ultimately, these changes are associated with deforestation, biodiversity loss and land degradation (Kilonzo 2014). LULC studies that have been done in several regions of different watersheds have documented deforestation in many river catchments. A study by Mwetu (2019), on Njoro River concluded thatin the upper catchment, the forest cover had decreased by 25% while open field with grass had increased by 58% within 27 years. Additionally, Nabwire (2019) in a study along Nzoia River indicates that over the years, the wetland vegetation has been replaced with a bare ground due to expansion of farmlands. In a study of spatio-temporal land use change by Akali *et al*., (2015) it projected that by 2020, forestland, water body and wetland would reduce by some percentage while that of cropland and grassland would increase as the population increased. Due to the growing population within catchments and requirements to meeting the ecological demand, sustaining increasing water demands as recorded by Hofmann, *et al*., (2011), is vital to any region. As a result of increased population and need for more land, the natural vegetation have been cleared and cultivated (Seguise *et al*., 2004). This has become a problem all over, even in marginalareas where grazing was predominant due to low rainfall (Onyando, 2000). Akali *et al,* 2015 continues to note however, that less attention has been given by people towards unfavorable climatic conditions coupled with rapid urbanization and intensive agricultural development. Intensive agriculture and other human activities have resulted in the degradation of land. It has ledto loss of top fertile soil due to erosion, high occurrence of floods, eutrophication of surface water bodies and siltation of rivers; hypoxia condition which results in losing aquatic biological diversityand low stream flows in dry periods (Donner 2004; Araujo and Knight 2005; Lim *et al*, 2005, Onyando *et al*, 2005). Land-use changes therefore require human intervention as it may also arise from natural causes as well (Joshi et al., 2016). Therefore, accurate and dependable information over land use and land cover is required to detect changes and to monitor the identified area and this will require the input of Remote Sensing and GIS (handled in section 2.6). This study also focused on the LULC changes on the upper reaches of the Rivers where they are dominated by forest.

2.3 The Influence of LULC Changes on Rivers Discharge

Rivers are said to have dried or reduced in level due to degradation of land, soil and water. Deforestation to create room for human settlement and agriculture has led to increased surface run-off resulting in soil erosion and thus siltation of water bodies. This eventually results in reductionin volume of discharge in a river (Imo, 2012). According to the report on climate change in Kenya, Mutua (2001) states that deforestation leads to increased runoff, increased soil erosion and thus may eventually cause significant increase in discharge as a result of increased sedimentation in riverbeds. According to Bruneau (2005) the major cause of increased flooding and decreased discharge of aquifers is due to loss of forest cover around the watersheds and further, this deforestation is changing the thermal regime of the landscape and rivers thereby increasing the rate of water evaporation. Mercy (2017) concurs with this statement by saying that loss of green cover increases both minimum and maximum temperatures. This argument has been supported byTemesgen *et al.*, (2018) who agreed that climate–vegetation interaction can affect the energy and water balance. It was observed that with increased reduction in forest land cover in the Njoro riverupper catchment, there was a reduced average annual discharge

(Mwetu, 2019). As natural vegetation is changing to agriculture, it leads to reduction in soil porosity through soil compaction, decreasing infiltration capacity and increasing the risks of soil erosion (Holder, 2004).

In the report of The New Humanitarian, Nuttal (2006), a spokesman to the United Nations Environmental Programme (UNEP), argues that extreme hydrological conditions in Eastern Africa can partially be due to deforestation in the region. He further mentions that trees beneficial functions are in the following two ways; trees funnel water into the underground aquifers where itwill be stored to supply rivers during drought; and trees hold soil from being eroded into the rivers as the eroded materials will cause siltation in the rivers.

Day and Evening (2005), postulate that forests soil behave like a 'sponge' which soak up water during precipitation and release it slowly within the watershed afterwards and it does this in a way that forest floors, with their leaf litter and porous soils, easily accommodate intense rainfall as infiltration takes place slowly until the soil is saturated. They further added that tree leaves hold some rainwater that evaporates directly to the atmosphere and leaves also reduce raindrop impact as gentler rain causes less erosion, hence less sediment to cause silting in river channels. In addition, Odhiambo in the New Humanitarian Report says that deforestation have resulted into flash river water discharge during heavy rainfall (Nuttal, 2006).Additionally, Conversion of land use from natural landscapes to agricultural or urban lands mostly affects the integrity of soil and native species assemblages and such changes can thus have impacts on watershed hydrology by influencing the rate of inception, infiltration, evapotranspiration and ground water recharge that yield changes to the timing and amount of surface and river run off (Chandler 2006). Bruijnzeel (2004) also adds that the removal of vegetation in a region may result in increased base flows if soil infiltration capacities are intact. A deforested catchment generally is said to have increased run off due to the minimal transpiration (Miller *et al*, 2002). The deforested watershed has a short time of concentration and the peak flows are larger as to when compared to forested catchment (Marloes, 2009).

Odira *et al*., (2010) in a study in Nzoia River conclude generally that deforestation in the catchment region affects stream flow in that during the rainy season, stream flow rate increases as compared with when there is forest. Additionally, Githui (2021) also observed higher stream flow as a result of reduced forests for agriculture. She adds that Crops generally demand less soil moisture than forests thus rainfall satisfies the soil moisture deficit in agricultural lands more quickly than in forests thereby generating more runoff. Forests have the effect of reducing runoff, thus the smaller the area the more the runoff. Other studies have shown that when agricultural land is tilled, compaction of lower soil horizons occurs and this lowers infiltration rates and increases bulk density (Ankeny, *et al*., 1990; Logsdon, *et al.*, 1990; Nidal, 2003). This compaction reduces water retention as rainfall saturates the soil profile quicker in agricultural lands than in the forested areas thus producing more runoff and with the growing population, large areas of forests upstream have been cleared for human settlement and crop farming and consequently, erosion and foreseeable soil slippage and landslides occur on annual basis (UNEP 2009). The continuous accumulation of sediments over years in the riverbed has made the channel of the river course to be above the general level (Paron, *et al*., 2013). Nabwire (2019) in a study along Nzoia River indicates that over years, the wetland vegetation, particularly forest has been replaced with a bare ground and thus increasing the river discharge.

2.4 Water and Soil Conservation Measures

The population along rivers is continuously growing and in a fast rate. This has led to increased demand for wood and thus over exploitation of trees for commercial purposes and to create land for agriculture. Loss of this vegetation combined with poor agricultural practices such as overgrazing and cultivation in marginal areas leads to severe erosion in case of a run-off (Burhenne, 2002). Soil is said to be a very valuable basic resource for farming and thus it needs proper management in order to sustain long term farming productivity and to prevent it from erosion (Nongmaithem *et al*, 2023). This natural resource has become increasingly depleting, rapid land conversion taking place and resulting into unsustainable land management and land degradation (Zeleke, 2010). The problem of land degradation especially the depletion of nutrients and soil erosion is a critical environmental crisis (FARM-Africa, 2005). Therefore, the question of soil conservation has become most crucial because the soil is very easily eroded within a very short time. At the same time, it should be noted that it takes hundreds of years to form one-centimeter thick layer of soil (Morgan, 2005) Soil loss is an environmental problem as well as a problem for agriculture (with the loss of organic matter and fertility). Sediment entering streams can destroy fish habitat and water quality especially when soil particles contain contaminants such as pesticides or nutrients. The purpose of Soil and

Water Conservation are; to control runoff and thus prevent loss of soil through erosion, to minimise soil compaction; to improve soil fertility; to conserve water and to harvest (excess) water (Tidemann 1996).

LULC changes generally impacts on soil and water quality as well, for instance, according to Mango *et al.,* (2011), Land use and management practices affect processes in a river basin such as erosion, surface run off, recharge and evapotranspiration. They attribute to poor management of soils, overgrazing, deforestation and settlements in river basins to degradation of river Mara. It hasbeen put forth that clearing of natural vegetation or forests in the field exposes the top soil to severeerosion (Onywere, 2005). On the other hand, increased erosion as a result of increased deforestation and agricultural activities on the upper part of a river led to sedimentation and siltation in the river (Mainuri *et al*., 2014) - in a study on Njoro River. UNEP (2001), noted that it is important for communities worldwide to have sustainable management of watersheds, conservation of soil resources and enhancement of the quantity and quality of water resources. These fore-mentioned statements then validate the need to look at the water and soil conservation measures in river watersheds.

From the foregoing different literature, it is clear that LULC changes have taken place such that natural vegetation, mostly forest, in several watersheds has been replaced with other land uses. Consequently, this have resulted in excessive erosion of topsoil and thus impacting on the fertilityof the land (Mainuri *et al*., 2014; Mango *et al*, 2011; Onywere, 2005). Erosion is seen to be a natural process that provides sediments and organic matter to water systems and further could lead to loss of soil fertility in crop land areas and deterioration in water quality through sedimentation (Ayivor and Gordon 2012). Therefore, Soil and water conservation methods would slow down the rate of flow of surface runoff thus enhancing infiltration and retaining the sediments on the farms (Bracmort *et al*., 2006, Tuppad *et al*., 2010, Vogl *et al*., 2016). China *et al*., (2017), in a study in Isiukhu catchment along river Nzoia, conclude that the major determinants of soil erosion are LULC, soil texture and the relief of the area and thus recommended that indiscriminate felling of trees, mono-cropping, over grazing; ploughing up and down the slope and other anthropogenic activities that expose ground surface for high surface run-off should be discouraged. They also add that poor management of resources, such as unplanned land clearing for cultivation and deforestation of the water towers has led to serious environmental and ecological degradation as well as reduced water volumes. UNEP (2001) noted that it is important to have sustainable management of watersheds and conservation of soil resources. According to Mango *et al*., (2017), if soil and water conservation measures are not taken into account, the cost of mitigating the degradation of ecosystems get higher while the crop yields persistently decline. Mwangi (2011), in a study in Sasumua watershed in Kenya observed that poor land use management activities suchas over-cultivation and overgrazing have caused increase in sediment load to streams and reservoirs and thus affecting water quality and reducing infiltration of water into the ground and consequently, because of this, flush flooding during rainy season and low flows during dry season have been noted. Soil conservation practices are tools the farmer can use to prevent soil degradation and build organic matter. A number of techniques have been employed in the soil and water conservation measures including agronomic, vegetative and structural (Muriuki *et al*., 2011). They also include: crop rotation, reduced tillage, mulching, cover cropping and cross-slope farming.

2.4.1 Agronomic and Vegetative Measures

Agronomic measures are cultural practices that promote soil and water conservation by reducing splash erosion, improving soil structure and reducing run off and they include increasing soil surface cover, intercropping, contour farming, cover cropping and agro-forestry, increasing soil surface roughness, and increasing both surface depression storage and infiltration (Muriuki *et al*., 2011). They further add that vegetative measures are similar to agronomic measures though their difference is that they are associated with perennial crops, grasses or scrubs, for example agro forestry technologies. According to FAO (1984), agronomic measures is use of vegetation, either alive or dead, in sufficient quantities to protect the soil surface from the direct impact of raindrops and to create a surface rough which will physically alter run-off and slow it down to non-erosive velocities. The role of agronomic measures in achieving of soil & water conservation has immense importance. It is important to understand and disseminate the different soil management practices used to cultivate the soil and grow the crops (Lynden & Lane, 2004).

Agronomic or biological measures utilize the role of vegetation in helping to reduce the erosion by increasing soil surface cover, roughness of the surface, surface depression storage and soil infiltration (Noordwijk & Verbist, 2000). According to Simpson (2010), agronomic practices are measures undertaken within the cropping area for crop production purposes and include practices such as intercropping, contour cultivation, minimum tillage, mulching, manuring, etc., which are usually associated with annual crops, are repeated routinely each season or in a rotational sequence, are of short duration and not permanent, do not lead to changes in slope profile, are not zoned and are independent of slope. The major agronomic soil and water conservations practices are: Strip cropping, mixed cropping or intercropping, fallowing, mulching, contour ploughing, crop rotation, conservation tillage, and agroforestry (Mati, 2005).

Mixed cropping: is also known as intercropping. It is the cultivation of more than one crop at the same time in the same field (Meine & Bruno, 2000; Andersen, 2005). mixed cropping provides small quantities of a grain of different kinds for home consumption at different times (Morgan, 2005).

Fallow system: Arable lands are planted with food crops for some years and then the land is fallowed for some time to allow the soil to rejuvenate (Meine & Bruno, 2000). This can be considered as an improved version of the traditional shifting cultivation (Burgers *et al*., 2005).

Agroforestry refers to a system of land uses in which different trees or shrubs are grown in association with different agricultural crops, pastures or livestock. Agroforestry is important in that it provide both ecological and economic interactions between the trees and other components(Young, 1989)

Contour Tillage: Is a tillage practice performed on the contour of the area applied across the slope of the land (Meine & Bruno, 2000). It involves ploughing, planting and weeding along the contour, *i.e.*, across the slope rather than up and down (Morgan, 2005). It also conserves soil, and due to increased time of concentration, more rainwater seeps through the soil profile to recharge groundwater. Summer ploughing leaves the soil highly absorbent of initial rains (Deborah, 2003).

Conservation Tillage: Is any method of soil cultivation that leaves the previous year's crop residueon fields before and after planting the next crop to reduce soil erosion and runoff, as well as other benefits such as carbon sequestration. The method tries to reduce labor in land preparation through tillage systems that promote soil fertility and soil water conservation. Conservation tillage applyingfour main principles: 1) zero or minimum soil turning, 2) permanent soil cover, 3) stubble mulch tillage, and 4) crop selection and rotations (Biamah et al., 2000).

Mulching: Mulches are ground covers that prevent the soil from being washed away, reduce evaporation, increase infiltration, and control growth of unwanted weeds (Deborah, 2003). Mulch can be organic crop residue, pebbles, or materials such as polythene sheets. Mulching prevents the formation of the hard crust after each rain. Organic mulches add plant nutrients to the soil upon decomposition.

Vegetative Barriers

They are normally grass that are grown in narrow strips along the contours of the field to act as barriers and helps in reducing the velocity of runoff, contains soil moisture throughout and traps the soil moving near the roots. Apart from this, vegetative barriers also generate income and foodfor livestock. A verity of fodder plants/grasses (Napier), Pulses and fodder trees are grown on earthen bunds in terraces while on sloping terraces other fruit plants/trees nutrients to soil and arefinancially beneficial for farmers (Mishra, 2019).

Strip Cropping is a kind of agronomical practice, in which normal crops are grown in form of relatively narrow strips across the land slope. These strips are so arranged, that the strips crops should always be separated by strips of close-growing and erosion resistance crops. Strip croppingchecks the surface runoff and forces them to infiltrate into the soil, which facilitates the concentration of rainwater (Morgan, 2005). This technique combines soil and moisture preservation aspects and is effective in the control soil erosion and loss in areas with too long slope length (Nongmaithem *et al*, 2023). The study continues to add that strip cropping is of different forms. These forms include the following:

Wind Strip Cropping: consists of growing crops that grow tall such as jowar, bajra or maize, and low-growing crop in alternately arranged straight and long parallel strips laid out right across the direction of the prevailing wind regardless of the contour.

Permanent or Temporary Buffer Strip Cropping: these types of strips are established to take care of steep or highly eroded slopes in fields under contour strip cropping.

Field strip cropping: its where crops are planted in parallel bands across a slope but not following contour lines.

Contour Strip Cropping: this involves growing of a soil-exposing and erosion permitting crop in strips of suitable widths across the slopes on contour, alternating with strip of soil protecting and erosion-resisting crop.

Natural Vegetative Strips: When land is ploughed along contour lines, certain strips are left unploughed, across the field on the contour (Garrity et al., 2004). The natural vegetation of the strips filters the eroded soils, slows down the rate of water flow, and enhances water infiltration, making them very effective for soil and water conservation. Researchers found that these natural vegetative contour strips have many desirable qualities (Garrity et al., 2004). Other agronomic practices according to Nongmaithem (2023) include:

Crop rotation: This is where different types of crops are grown in the same peace of land in sequenced seasons. It is commonly practice on sloping soils because of its potential to save soil and it reduces fertilizers, need (Nongmaithem, 2023).

Cover Crops: Cover crops are vegetations planted to control soil erosion, enhance soil fertility, enrich and protect soil and to enhance nutrient and water availability, and the quality of soil. Cover crops are beneficial to soils used for agricultural production in that they are helpful in increasing and maintaining microbial biological diversity in soils. The efficiency of the cover crop majorly relies on close spacing and development of good canopy for interception of rain drops in order to expose minimum soil surface for erosion (Nongmaithem, 2023).

Role of Agronomic Practices on Soil and Water Conservation (SWC)

Agronomic Practices are important in keeping the soil in its place from erosion and also in maintaining its fertility (Morgan, 2005; Young, 1989). To do so, SWC requires control of erosion, maintenance of organic matter and soil physical properties, maintenance of nutrients, and avoidance of toxicity (Young, 1989). Therefore, agronomic practices provide a protective role to the soil. This is by its prevention of soil from loss by its plant canopy, litter effect, and reduction of velocity of runoff mechanically by runoff barrier function (Young, 1989; Kilewe et al., 1988). This can be viewed in its interception effect where the plant canopies, litter and mulching intercept rain by decreasing the amount, intensity and the spatial distribution of the precipitation reaching the soil surface (Kilewe *et al.,* 1988). This protects the soil surface from the direct impact of raindrops which can cause a splash and sheet erosion, a breakdown of the soil structure, sealing of the surface and reduction of infiltration rates (Morgan, 2005; Young,1989).

Agronomy also is important in the modification of extremes of soil temperature through a combination of shading by canopy and litter cover (Young, 1989). In the parkland practice, *Faidherbia albida* is one example of an important tree that increases the soil-improvement including nutrient cycling and crop yield in Malawi and in Ethiopia (Buck et al., 2007).

2.4.2 Structural Measures

They are physical, constructed features formed using soil, stones or masonry, designed to protect soil from uncontrolled run-off and for water harvesting and they include terraces, diversion ditches and retention ditches and micro-catchments (Muriuki *et al.*,2011). The main Soil and water conservation structural measures used on croplands comprise diversion ditches (cut-off) drains, retention (infiltration) ditches, terraces and waterways (Mati 2005). Another study by Mati, (2007) has shown that the use of contour farming is useful in reducing soil erosion by 50% compared to up and down cultivation. It is also important to note that contour farming has a positive effect in reducing sediment yield

(Arabi *et al*., 2008; Brunner *et al*., 2008). Contour farming creates surface roughness blocking the surface runoff and encourages infiltration as water pond in the depressions. This reduces the erosive power of surface runoff and thus reduces soil erosion (Quinton and Catt, 2004; Arabi, *et al*., 2008). The infiltration of water will in effect enhance the recharge of the shallow aquifer and water will be released to the streams as base flow.

Terracing is one of the soil conservations measures that have been mentioned to reduce sediment loading into streams and reservoirs by Gassman, *et al*., (2006). Terraces are conservation structures which comprise of a series of horizontal ridges made on a hillside (Neitsch *et al.*, 2005). Arabi, *etal*., (2008) said that terraces are helpful in enhancing the ponding of water on the surface hence allowing higher rates of infiltration and that the velocity of the remaining surface runoff would be reduced and thus the erosive power would be significantly lowered. They further continued to argue that terraces also reduce the length of the slope which in turn lowers the peak runoff rate. Ruto, *et al*., 2017 in a study in Narok County, mention that terracing led to reduction in soil erosion and significantly leads to increased maize and beans yields. Despite their effectiveness in controlling runoff, terraces and stone bunds can be the source of erosion if poorly maintained or abandoned over time (Taye *et al*., 2015). In a study by Gathagu, *et al*., (2017) in Chania –Thika, it was realized that terraces and grass strips were the main conservation methods used by farmers.However, they were not managed properly leading to their collapse and the soils were washed away by surface runoff. It is then notable that when soil and water conservation measures are improved, they can reduce moisture stress and improve crop yields associated with rain-fed agriculture and that, the high mean water erosion rates in the river basins can be attributed to negative land use and land cover changes as well as neglect in adopting effective soil water conservation measures (Musiyiwa, *et al.*, 2016). Zhunusova, *et al*., (2013) indicated that the singleuse of terraces had negative impact on crop yield in the Lake Naivasha basin while Baumhard (2014) found out that mulching and ground cover can be ineffective in controlling runoff flow on croplands with steep slopes. Accordingly, it is important to combine control measures (multiple soil conservation practices) for effectiveness (Willy *et al*., 2014).

Leveled bench terraces and earth banding on existing slopes are seen as common earth structure in Kenya. Sometimes, and especially in the highlands, steps are constructed across hillsides and strips of crop residues are covered with soils dug from above. The resulting incorporation of organic matter increases soil fertility and enhances infiltration through macro porosity as well as increased water retention in soils (Karuku *et al.*, 2012; Karuku *et al*., 2014,). Ogweno (2009), in study in Malewa watershed in Kenya, realized that a vegetation filter strip can reduce sediment yield by approximately 95%. The efficiency of the filter strips to trap sediments depends on the factors such as the width, vegetation type, density and spacing, Manning’s roughness coefficient, flow concentration, soil type, sediment particle size and the slope (Yuan *et al.*, 2009; Abu-Zreig, 2001; Fox *et al*., 2010; Arnold and White, 2009).

Field bunds (or earth bunds), check and plugs and farm ponds have also been used as a means of soil and water conservation measures (Karmakar 2020). He says that Earth bunds are barriers to run off from the upper streams onto the cultivated land; check and plugs are stone basedconstruction that allows water to pass through as the soil is retained.

They act like traps of soil in a mixture of water and soil and thus a means of soil erosion prevention and control. He defines farm ponds as holes dug to harvest rain water and to act as storage for this water for future use.

Cover crops have also been used in Kenya as a Soil and Water Conservation Measure (SWCM) (George, 2018). Cover crop is any annual, biennial or perennial plant grown as a mono- or polyculture to improve any number of conditions associated with sustainable agriculture (Lu *et al*., 2000). Cover crops are fundamental sustainable tools used to manage soil quality, water, weeds, pests, diseases and diversity in an ecosystem (Mannering *et al*., 2007). Keeping the soil covered is a fundamental principle of conservation agriculture. Crop residues are left on the soil surface to protect soil surface after harvesting (Karuku *et al*., 2012; Karuku *et al*., 2014). Additionally, Agroforestry has been mentioned to be another technique that is used as SWCM. Karuku (2018) describes agro-forestry as a land use system where trees are grown in association with agricultural crops and agro-forestry has the potential to arrest land degradation.

2.5 Soil and Water Assessment Tool (SWAT) Model

The Soil and Water Assessment Tool (SWAT) is a model of small watershed basin that simulates the quantity and quality of surface and ground water and foretells the environmental impacts of land use, land management practices and climate change and the flow of water in and out of the hydrological system, informs all the processes in the SWAT model (Arnold *et al.*, 2013). The model was created to foretell the hydrological response of the un-gauged watersheds to both natural inputs and man-made interventions and it can analyze water, water quality and sediment yields. It is continuous and long-term model for watershed simulation. The model uses inputs that are readily available; is physical; is efficient to computationally operate and is capable of simulating long periods for computing the effects of the changes in management (Anold *et al*., 1998; Neitsch *et al*, 2002). The components that can be used for the model includes soil, temperature, hydrology, weather, nutrients, plant growth, pesticides and land management. The advantage of the model is that it does not need much calibration and thus un-gauged catchments without monitoring data can be modeled successfully (Anold *et al*., 1998; Neitsch *et al*, 2002).

The SWAT model is currently regarded as a versatile model used to integrate environmental processes that support more effective watershed management (Gassman *et al*., 2005). The SWAT model was developed and updated from the models of Arnold of the United States department of Agriculture (USDA) in the early 1990s, then expanded to predict the impact of land management practice on water, agriculture, sediment and chemical yields on watershed scale with temporal and spatial aspects (Krysanova and Arnold, 2008; Neitsch *et al.,* 2005). Daniel *et al*., (2011) postulated that SWAT is deterministic, continuous watershed model that operates on daily and hourly basis and the model was developed by the Agricultural Research Service of the United States Department of Agriculture. It can model changes in the hydrologic response of the catchment, water quality, and erosion and estimating the effects of land use and land cover changes and in order to model a hydrological unit, entire catchment is divided into sub catchments which are further divided in to hydrologic response units (HRU) based on land use, vegetation and soil characteristics (Arnold, *et al.,* (2013); Neitsch, *et al*., (2011)). The delineation of the HRUs in a sub-watershed is determined using AVSAT-X built-in tools (Di Luzio *et al.,* 2004). (Neitsch *et al.,* 2011, further postulates that SWAT then estimates run off of each HRU separately and then give out the total runoff for the entire basin. Master water balance approach is used in SWAT model to compute run off volumes and

peak flows (Arnold, *et al*., 1998) and is expressed as;

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

Where SW_0 is initial soil water content and SW_t is the final soil water contents on day *i*.

All other measurements are taken in millimeters and time (t) is in days. The equation subtracts all forms of water loss on day *i* from precipitation on day *i* (R_{day}) including surface runoff (Q_{surf}), evapotranspiration (E_a), loss to vadose zone (w_{seep}) and return flow (Q_{gw}) (Arnold *et al*., 2009). By manipulating this equation, the model can predict changes in variables of interest like runoff and return flow and the input data to be used in the model includes land cover map, Digital Elevation models (DEM), channel geometry and soil Map (Abbaspour, *et al.*,2018; Arnold *et al*, 2012).

In order to simulate a watershed, the basic hydrology of the area must first be known and presented in mathematical relationship that represents the real hydrological conditions of that region (Gassman *et al.,* 2007). SWAT model has also been used to analyze soil erosion changes in relation to the effects of the soil management practices such as terraces and contours and the results showed that there was some impact. Thus SWAT model is seen to be a tool to predict water flow in large scale watersheds and thus very important tool for water resource planners and managers (Abu- zreig and Bani, 2021).In using the SWAT model, the soil profile is sub divided into layers with differing soil-water processes that includes evaporation, plant uptake, lateral flow, infiltrations and percolation to lower layers. The soil percolation component of SWAT uses a storage routing mechanism to foretell flow through each soil layer in the root zone. The down-ward flow occurs when the yield capacity of the soil layer is exceeded and the layer below is not saturated. Groundwater flow contribution to the total stream flow is simulated by routing a shallow aquifer storage component to the stream (Arnold and Allen 1993; Di Luzio *et al.,* 2004)

SWAT model has been used to assess climate change variability as well. Manoj *et al.*, 2006 used it in the upper part of Mississippi watershed to analyze the sensitivity of climate change on river flow variability and the research results indicated marked changes on the mean annual river discharge. Their conclusion was that there are immense uncertainty changes resulting from climate change. Githui *et al*., 2009, as well did a simulation between stream flow and various climatic change scenarios using the model and regression relationships between changes in climate (rainfall and temperature) and runoff were generated and the results showed that a change in climatic patterns affects the river discharge.

2.6 SUFI-2 Algorithm in SWAT CUP

Calibrations using SUFI-2 algorithm is performed with a series of iterations and these iterations include numerous simulations, where each is fed with the results of the previous one and thus it results in achieving optimised simulated variable (Abbaspour *et al*., 2007).

Abbaspour continues to say that the iteration yields a set of values assigned to the parameters that describe the hydrological processes, physical characteristics and dynamics of each HRU. Each of the new iteration presents intervals of the parameters recursively closer to the real value and the aim of this is to limit the uncertainty in the initial ranges of the parameters as their measurements are often unavailable (Abbaspour *et al.*, 2018).

Immediately after initial model set-up, the sensitivity, calibration and validation and uncertainty analysis of the model are executed in the SWAT CUP software package and the objective of sensitivity analysis is to gain better insights of the relative impacts of input parameters on the model output (Abbaspour *et al.*, 2015). The process of calibration consists of adjusting the model parameter values so that the simulated (estimated) values approach the observed values (Arnold *etal*., 2012). It should also be noted that the model does not know the initial simulation conditions and therefore a warm-up period is required (Li *et al*, 2015).

2.7 GIS and Remote Sensing

Remote sensing is defined as art and science of acquiring information of an object, area or phenomenon on the surface of the Earth (Lillesand *et al*., 2008). He further adds that it is the study satellite imagery and aerial photographs as they have the capability of differentiating land use land cover types by using variation in electromagnetic signatures. GIS on the other hand, according to United States Geological Survey, is a system of computer that is capable of inputting, storing, manipulating and displaying geographically referenced information (USGS 2007). The view of Earth from space enables researchers to critically understand the whole round influence of man activities on the natural state of the earth's surface and remote sensing and GIS tools can provide the most cost effective record of LULC accurately and in a more timely manner (Ridd and Liu 1998; Chen *et al*., 2013).

Satellite based remote sensing can capture electromagnetic in ranges (visible, infrared, microwave)and vary the electromagnetic spectrum into different separate bands. This will allow for the extraction of information on the variability of Earth's surface because of the reflections from the surface to different electromagnetic wavelengths (Lillisand and Kiefer, 2006). Remote sensing is advantageous over ground based observation in that it facilitates observation of extensive land coverage. This is accomplished by the use of cameras, multispectral scanners, RADAR and LiDAR sensors mounted on airborne (aircraft or balloon) or space borne (satellite) platforms (Roy and Roy, 2010).Remote sensing had advanced tremendously and its improvement has enabled repeated observations of the earth's surface due to improvement on the sensor capability in termsof spatial resolution, spectral resolution, radiometric resolution and temporal resolution (NAP, 2008).

Remote sensing data and geographic information system (GIS) are very essential tools in hydrology and land-use and land cover analysis due to the fact that most of the data required for hydrological and land-use/land cover analysis can easily be obtained from remotely sensed imagery (Gumindonga, 2010). He further notes that remote sensing has the capability to acquire spectral signatures instantaneously over large areas and these signatures allow for the extraction of information pertaining to land-use and land cover.

Remote sensing and GIS when combined with other computer-based modeling tools, are said to be popular and efficient means for simulation of current and future LULCC and hence important for land use planning and the management of natural resources (Herold *et al*., 2003; Araya, 2009). Remote sensing and GIS together has been used effectively to identify environmental features such as urban sprawl, vegetation cover, forest changes and the changes in LULC over a certain period (Helmer *et al*, 2000). Castellana *et al*, (2007) declared a new approach of change detection based on the combination of unsupervised classification and supervised classification. Viewing Earth from space enables researchers to critically understand the all-round influence of man activities on the natural state of the earth surface and GIS and remote sensing tools can provide the most cost effective record of land use land cover accurately and in a timelier manner (Ridd and Liu 1998, Chen, *et al* 2013)

Satellite imagery has been used by many researchers on analysis of change detection as it is capableof capturing LULC changes. As compared to other methods of data collection such as use of aerial photography, satellite imagery has become dominant because of availability of multiple satellite sensors, high geometry precision and the short revisit time interval (Stabile 2012). Gumindonga (2010) argues that LULCC can be analyzed over a period using Landsat Multi Scanner (MSS) data and Landsat Thematic Mapper (TM) data after image classification techniques have been applied.

Historically, Landsat use optical or infrared sensing in observing the Earth’s surface. National Aeronautics and space administration (NASA) started the program in 1972 and then it turned over to National Oceanic and Atmospheric Administration (NOAA), and years later, the citizens were given free access to its information by the governmental body, the United States Geological Survey(USGS). Since then, Landsat 1 to Landsat 8 satellites have been launched to space but the first four have failed, while Landsat 5,7 and 8 are still operational to date. The sensors used for Landsat includes; multispectral scanner (MSS) – which as used by Landsat 1 to Landsat 5; thematic mapper(TM) which was operational in Landsat 4 and Enhanced Thematic Mapper Plus (ETM+) which is carried by Landsat 7 (USAID, 2006). The use of Landsat imagery is currently open and free, as from 2008 and everyone can access it from USGS website (USGS, 2013). The consistency of Landsat images has over time allowed for comparison and thus one can track the changing history of a place either, monthly, yearly or even over decades (USGS, 2013).

In Kenya, satellite imagery has been used to show the effects of anthropogenic changes on land use. For example, Mercy (2017), used the satellite images to relate land use and land cover change to the changes in climate. Additionally, it has also been used by Lilian (2019) in analysis of LULCC on water availability and management. It has further been used in interpretation of LULCC on discharge regime of Njoro River (Mwetu, 2019) and Twesigye, *et al*., (2011) used thesame to identify pollution hotspots. The classes of LULC established from satellite data are digitized and then georeferenced for geospatial analysis of the parameters in the study area (Twesigye *et al*., 2011)

2.8 Theoretical Framework

Theoretical framework is defined as the presentation of a theory that explains a particular problem (Creswell, 2013). It identifies a plan for investigation and interpretation of the findings. The common property theory was used as a guide to this study. This theory was proposed by Ciriacy- Wantrup and Richard (1975) and it was advancement from “the tragedy of the commons” as put forth by Hardin (1968). The Common property theory in principle is that the resources are shared or used commonly by all members without any restriction or regulation. The resources are commonly owned and everyone has free access to it (or them). The commonly held natural resources have been abused. Resources that have been seen to be commonly owned include natural forests, grazing land, fisheries and water resources. Watershed has natural resources such as foreststhat have free access to all within the region. It needs a group ability to establish governance system to effectively manage the watershed commons (Kerr, 2007). This theory was applied by Mogosi,(2015) to assess land use land cover change and its effects on stream. It was also applied in the study of watershed management by Kerr (2007). Thus, the theory is relevant to this study as it willlook at the land cover resources such as forests that are being altered in the water catchment. Everyone at the watershed freely use forest products and thus causing changes in the land use andland cover.

2.9 Conceptual Framework

A conceptual framework illustrates what is expected of the research. It defines the relevant variables for the study and maps out how they might relate to each other (Bas, 2015). This study considered LULC change as the independent variable (Figure 2.1). LULC changes on the watershed are likely to impact on the dependent variables such as river water discharge and soil erosion. The intervening variables for this study are the soil and water management practices andpolicies, slope of the area, rainfall and soil. The study also had the following assumption: Climatechange in the area is insignificant and thus will not be considered to alter the river discharge within the time of study. This assumption is important in this study because one can claim that climate change is the root cause of the changes in the river flow rate, whereas on the contrary, the study holds that changes in the LULC is the cause of changes.

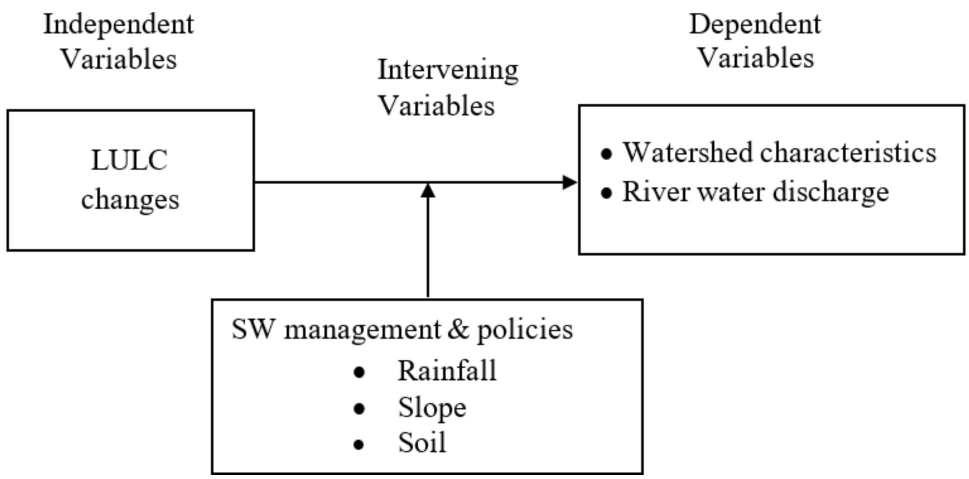

Figure 2.1: Conceptual framework

Source: Author

2.10 Knowledge Gap

There was need to study how land use and land cover change in Chepkaitit and Moiben Rivers' watershed led to change in river discharge. From other studies, like that of Odira (2010) and Githui(2017), there is mention of deforestation leading to increased flow rate in relation to the lower part of the river as all of Nzoia river was under study. However, this study then only focused on the upper catches of the river where the altitude is high and much of the government forest resources are located. It is this forest resource that is used to conserve the water towers (Cherangany and MtElgon towers). There was also a need to look at LULC changes that have taken place in Chepkaitit and Moiben rivers watersheds from 1980 to 2020 so as to establish the trend with time. From the foregoing literature, it has been found out that the impact of LULC changes on river discharge in Moiben.

CHAPTER THREE:

RESEARCH METHODOLOGY

3.0 Introduction

This chapter contains the area of study and the various methods that were adopted in this research.It covers the research design, population size, sampling methods, data collection techniques, data analysis, presentation of analysed data and the ethical considerations in the study period.

3.1 Area of Study

The area under which this study was carried out is Chepkaitit and Moiben Rivers' watershed found within the upper part of Nzoia River basin in Kenya (Figure 3.1). The western escarpment of Cherangany hills forms an important source to Moiben and Chepkaitit rivers (Cheboiywo, *et al.*, 2004). This watershed was chosen because it is found in high altitudes, has much forest which is facing pressure from the increasing needs of human population and its climatic conditions have no significant change. Additionally, it is part of the area that I spent my early childhood and partly I learnt that it was at a risk if the rate at which the people were infringing into its natural resources would not be considered a concern to the public and resource managers. Chepkaitit and Moiben Rivers are located between the coordinates 35020'01.5''- 35007'57.6''E and 1002'18.1''- 0055'06.9'' N. (WGS 84). It forms part of the upper catchment of the 12 903 km^2 Nzoia River watershed.

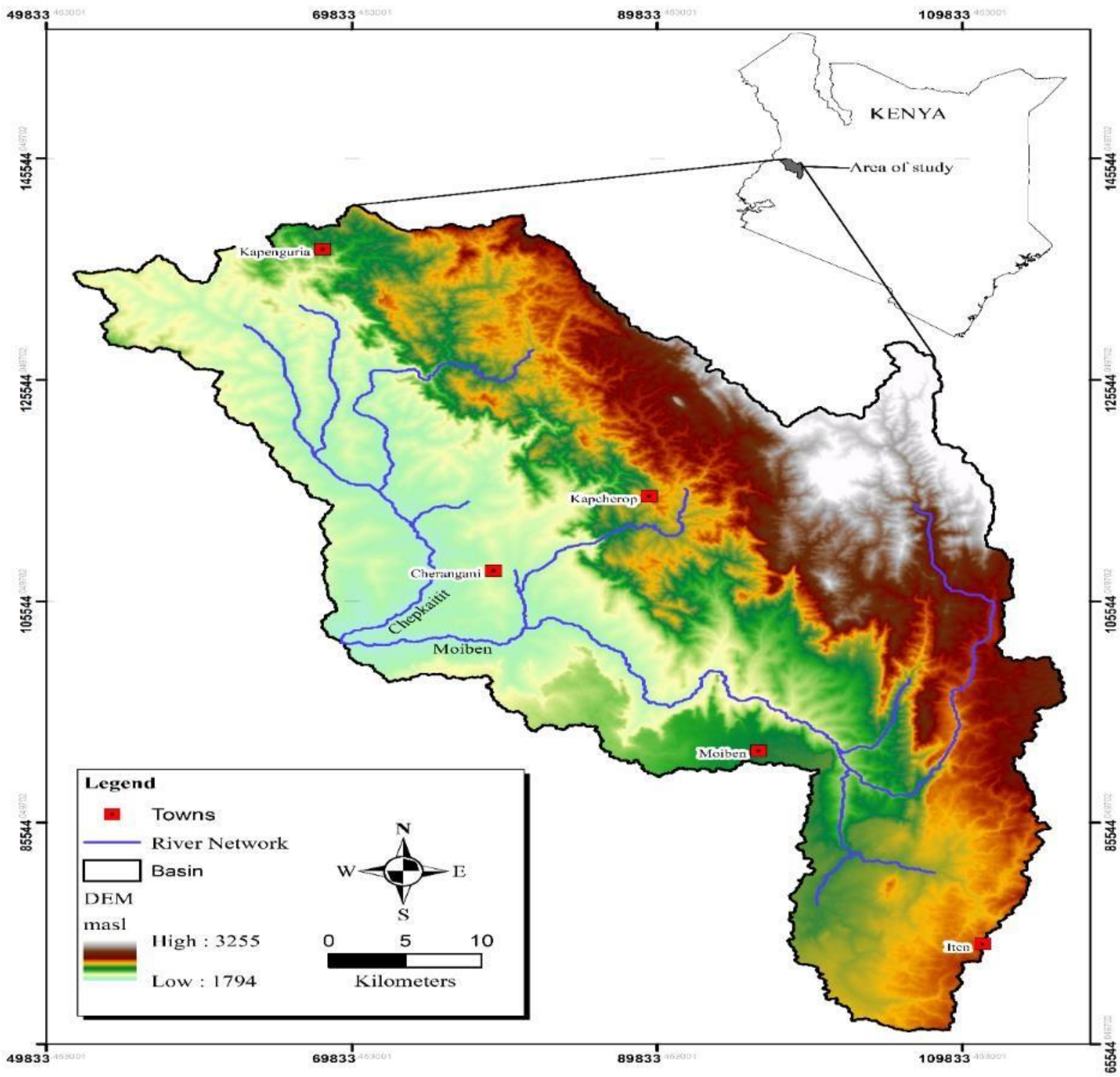

Figure 3.1: Map of study area

Source: Author

The Moiben and Chepkaitit watershed has a highland equatorial climate with diverse relief features. The mean annual rainfall in the area is 1124 mm, which occurs in one long season from March to September with two distinct peaks in May and August (Jaetzold and Schmidt, 1983). The average rainfall in Cherangany water towers ranges from

800mm in the North to about 1500mm in the west, with cool and humid weather conditions (Kenya Forest Service, 2015). It further notes that the average air temperature in the region is 14 °C during the wet season, with a maximum of 30 °C during the dry season and a minimum of 7 °C in the coolest season. January isthe hottest period, while July is the coldest period. Cambisols form the major soil group in the watershed (around Cherangany region) and is characterized by good drainage, good structure, varied acidity and high organic matter (OM) content (Kenya water Towers Agency 2020).

The Moiben and Chepkaitit Rivers originate on the western side of the Cherangany hills escarpment at 2400 metres above sea level. Chepkaitit River originates from Mt. Elgon and the Western part of Cherangany hills forest ecosystems. Moiben River on the other hand is approximately 81 km long from its source in the Kipkunnur forest to its confluence with the Kapolet River, where they join to form the larger Nzoia River. The rivers join Nzoia, which drainsto Lake Victoria. (GoK, 1973).

The land-use systems and practices in the basin broadly range from forestry, small-scale farming to large-scale mechanized agriculture. The basin is an area of high agricultural potential and is densely populated, which influences land use. The river drains a forested area at its upper reachesbefore entering a valley where mixed farming is practiced.

3.2 Research Design

The research employed both descriptive and correlational research designs. It involved temporal analysis of LULC changes using ArcGIS and modelling the influence of LULC changes on river water discharge in SWAT. The descriptive design was used in the assessment of the different LULC types and change over time and in documentation of soil and water conservation measures.The descriptive research design will be applicable in this study since it was applied by Hugo *et al.*,(2007) to analyse the spatial and temporal pattern of soil water content in an agroecological production system.

The relationship between the LULC changes and river-flow used correlational research design to establish the magnitude of associations through application of SWAT. This design was applied by Akankasha *et al*., (2023) to assess impacts of land use dynamics on changes in hydrological variables.

3.3 Target Population

The target population for which the data was to be collected from was then purposively identified. Target population is a universal set of the study of a member's real or hypothetical set of people, events or objects to which an investigator wishes to generalize the result (Lyon, 2007). The targetpopulation that was used for this study was the heads of the households from the two sub-counties. The two sub-counties of Moiben and Trans Nzoia East formed two strata where the population size was drawn from. From the 2019 Kenya Population and housing census, the households that were found in Moiben sub-county and Trans Nzoia East sub-county were 46,729 and 50,017 respectively. The targeted population under study was thus 96,746 heads of the households.

3.4 Sample Size and Sampling Techniques

Sampling is a process which allows data to be collected from a small sample size within a projector programme, and then used to come up with conclusions about the target (whole) population (Bhardwaj 2021). A sample size on the other hand is a small set of the whole population that is used to give the general views of the target population (Kothari 2004).The sample size must be a representative of the population on which the researcher would wish to generalize the research findings (Mugenda and Mugenda 2003). Sampling technique is the act of selecting a suitable sample or a representative part of a population for the purpose of determining characteristic of the whole population (Frankel &Wallen, 2008).

Based on a target of 96,746 households in the study area, a total of 383 households were sampled as guided by Krejcie and Morgan (1970), sample size table in Appendix c. Stratified random samples were then drawn from the two strata, where 186 household heads from Trans Nzoia East and 197 from Moiben were used. This study, however, was faced with some hurdles in the field in that the whole 383 questionnaires were not filled. The reason for this is because most of the respondents avoided to be questioned, bearing in mind that the questionnaire used was paperless and more like an exam to them. Additionally, this research was carried out during a period of crisis(between the year 2020 and 2021) when covid 19 was at its peak. The study thus managed to collect data from 300 household heads. More than half of the samples (52 percent of the total) were selected from Moiben because more informants were willing to give their information and the houses were not very close to each other. The households being very close meant they would provide the same information which would not have adequately represented the results. In the case of Trans Nzoia East stratum, 48percent of the total samples were taken because most of the household were very close due to the steepness of the land. Also, most people were not willing to give much information (because they had a feeling that the information on their lands could be used to grab their lands). However, when the data was being cleaned, the coordinates of others had almost same record and thus they were merged resulting to a population of 219. The paperless questionnaire records the location in coordinates and so if taken very close, it tends to overlap with other coordinates and the dominant coordinate remain. Bearing in mind that the questionnaire was administered by three different people, the same locations coordinates might have been taken unknowingly. But since more than 85% of the questionnaires were administered by the researcher in person, this sample clearly represented the area since the population was homogenous in characteristics all over the study area.

Analysis of LULC types and changes was carried out using the remotely sensed images of the Landsat satellite series. Landsat was chosen for this purpose because of its long serving history with better resolution of the spatial data sufficient for the study. The period of LULC change analysis intervals were 20 years starting from 1980, 2000 and 2020. This 20-year interval gave sufficient time for change to be detected.

3.5 Data Collection Techniques

Creswell (2003) indicates that research techniques are the tools used in the collection of data on the phenomenon of the study. The data used for this study included both the primary and the secondary sources. The primary source of data made use of paperless questionnaires while the secondary data sources included the satellite imagery and downloads from the different websites.

3.5.1 Primary data

Data on soil and water conservation measures was collected primarily using survey questionnaire. A questionnaire according to Mugenda and Mugenda (2003) is a list of standard questions prepared to fit a certain inquiry. This survey was conducted using paperless questionnaire developed and deployed in Kobo Tool-Box platform. This kind of questionnaire was first developed, then it was coded, the equations in the questionnaire were coded, then it was deployed and used for data collection. Paperless questionnaire was chosen for this study because it was more convenient and flexible and the data collected is well organized and its availability is immediate. Another advantage of this kind of questionnaire is that it locates the exact place on which the data was takenfrom; therefore, one will not forge the data, but move to several locations to collect the data.

3.5.2 Secondary Data

The secondary data was sourced from Landsat images downloaded from the USGS website asdiscussed below:

LULC Data

To discriminate LULC changes in the watershed over the study period, Landsat satellite data was used. The Landsat satellite imagery data was downloaded from United States Geological Survey (USGS) website, (https://earthexplorer.usgs.gov). The downloaded data was already geo- referenced with the World Geodetic Survey (WGS) 1984 datum and was projected to Universal Transverse Mercator (UTM) Zone 37N. The data for

LULC types of the year 1980 used Landsat 2 with a resolution of 60 meters and 180/059 path/row scene covered; for the year 2000 Landsat 7 with a resolution of 30 meters was used and for year 2020 Landsat 8 satellite image with a resolution of 30 meters was processed. For both Landsat 7 and Landsat 8, three imagery scenes were downloaded covering paths/row 170/059 (zone 36N), 169/059 (zone 37N) and 169/060 (zone 36N). Figure 3.2 shows the satellite images used in the three time periods of 1980, 2000 and 2020.The year 1980 LULC types, data used Landsat 2 satellite imagery of 16th May 1979 as this was the closest to 1980 without clouds. Landsat 2 imageries have 4 bands and the useful bands for vegetation analysis are band 4 (green band), band 5 (red band) and band 6 (blue band) all with a 60 meters ground resolution. The year 2000 LULC data used Landsat 7 satellite imageries of 27th January 2000 for path/row 169/059 and 169/060 and 6th February 2000 for path/row 170/059. Landsat 7 imageries have 7 bands and the useful bands for vegetation analysis are band 4 (green band), band 5 (red band) and band 6 (blue band) all with a 30 meters ground resolution. The year 2020 LULC data used Landsat 8 satellite imageries of 11th March 2020 for path/row 169/059 and 169/060 and 7th January 2020 for path/row 170/059. The Landsat 8 imageries have 9 bands and the useful bands for vegetation analysis are band 3 (green band), band 4 (red band) and band 5 (blue band) all with a 30 meters ground resolution.

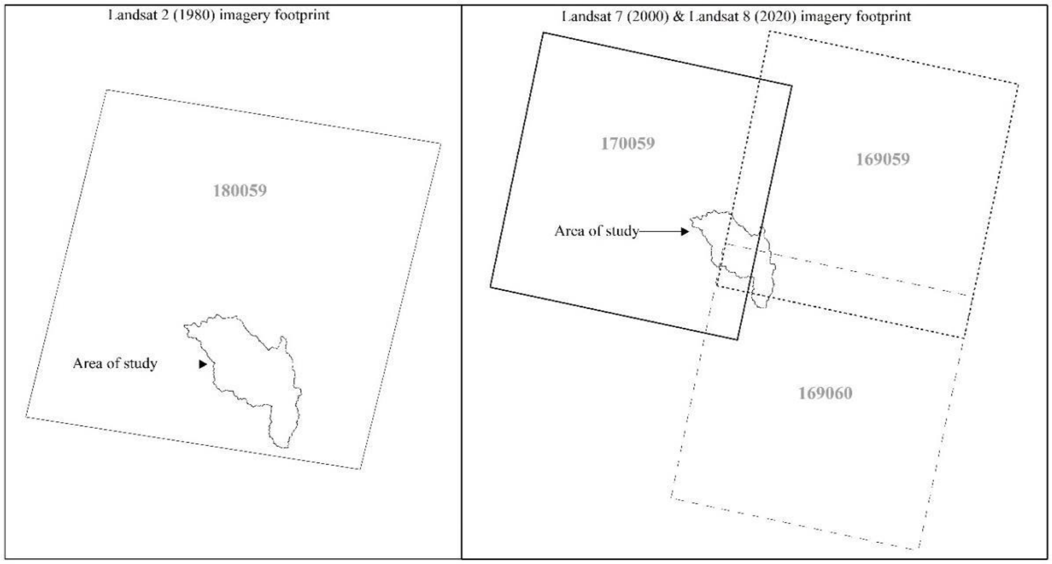

Figure 3.2: The downloaded imagery data footprint

Source: Author

Climate Data

The SWAT model makes use of weather data namely temperature, precipitation, wind, relative humidity and solar radiation parameters among others. The 1st Jan 1982 – 31st Dec 2013 weather data was downloaded from the "Global Weather data for SWAT" website (https://globalweather.tamu.edu/) while 1st Jan 2014 – 31st Dec 2020 was downloaded from (World Weather for Water Data Service (W3S) (https://www.uoguelph.ca/watershed/w3s/). This weather data was downloaded by selecting the location of interest in the map for this research the climate data was downloaded in ArcSWAT compatible format.

Soil Data

Soil data is a critical input for any hydrological simulation model. Soil properties (commonly texture and hydraulic conductivity) affect hydrologic processes such as infiltration and lateral transport of water in the soil. The soil data used by SWAT was divided into two major groups according to their characteristics; physical and chemical. In this study, physical characteristics of the soil data was considered since they control the motion of water through the soil profile and thus have a major impact on the cycling of water within each hydrologic response unit (Neitsch, *et al*, 2011). Soils were generally classified into different hydrologic response units (which comprise soils with similar runoff potential under similar storm and surface cover conditions) based mainly on their infiltration characteristics. Processed and classified spatial soil data for use in the SWAT model was downloaded from FAO website (https://swat.tamu.edu/media/116406/af_soil.zip) (figure 3.3).

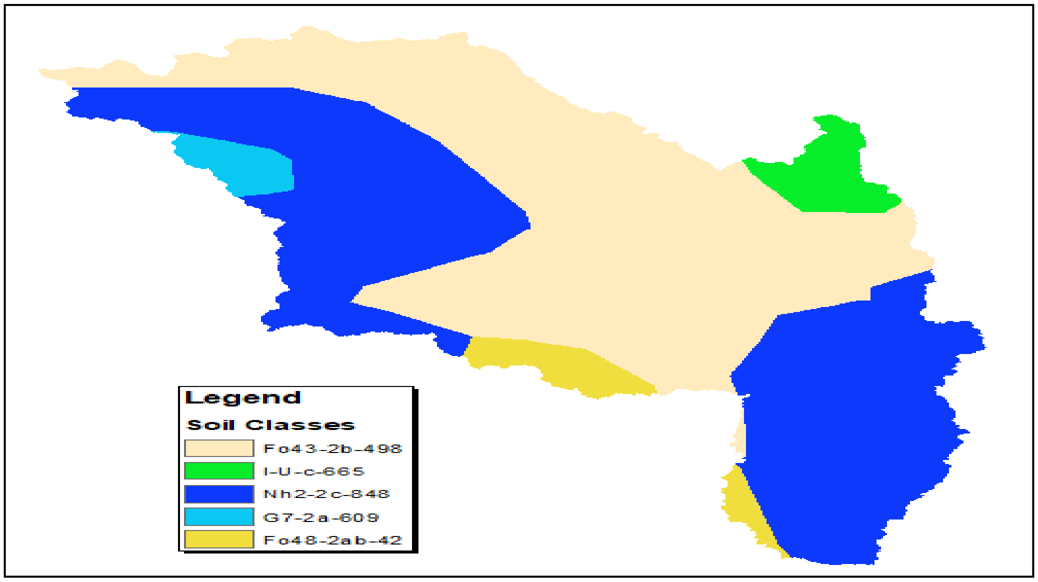

Figure 3.3: Map of different classes of soil

Source: Author

Slope Data

The slope data of the watershed was derived from DEM data that was downloaded from USGS website (https://earthexplorer.usgs.gov). A Digital Elevation Model (DEM) of the study area (figure 3.4) at a 30 by 30 meters resolution was obtained. The DEM was used to delineate the topographic characterization of the watershed and to show the hydrological parameters of the watershed such as the slope, flow accumulation, flow direction and stream network. By use of correct hydrological DEM, an accurate flow accumulation and direction grids can be obtained andthe grids will ensure that run off flow estimates and the boundaries of the watersheds can be clearly delineated (Jenson and Dominque 1988).

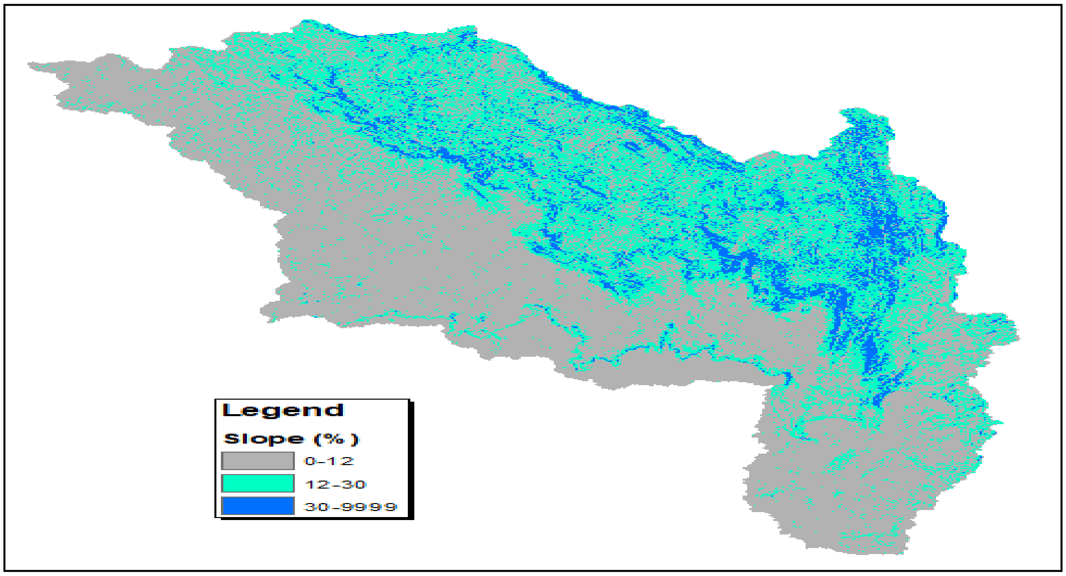

Figure 3.4: Elevation data in the area under study

Source: Author

3.6.1 Data Processing and Analysis

3.6.1 LULC Types

The downloaded bands of the Landsat scenes were separate image files (.tiff) which were layer stacked for classification. The satellite imageries pre-processing, processing and analysis was doneusing ArcGIS version 10.5. The Landsat images were pre-processed so as to prepare them for classification analysis. Using the three bands for vegetation analysis, composite images were generated and extraction of the area of study was done (figure 3.5). A false composite image is animage that bare colours that does not resemble the actual colour of the feature in reality, whereas true colour consist of the three primary colour (red, green and blue) combined. For instance, in false colour composite image, vegetation in an area appears in different shades of red since it hashigher reflectance of Near Infrared (NIR) (Imam 2019). For this composite imagery' further imageprocessing techniques were applied for production of the maps of the area in the three periods. Thesatellite image classification was performed through onscreen digitization. Further, processing andanalysis of these spatial data was carried out in the same environment.

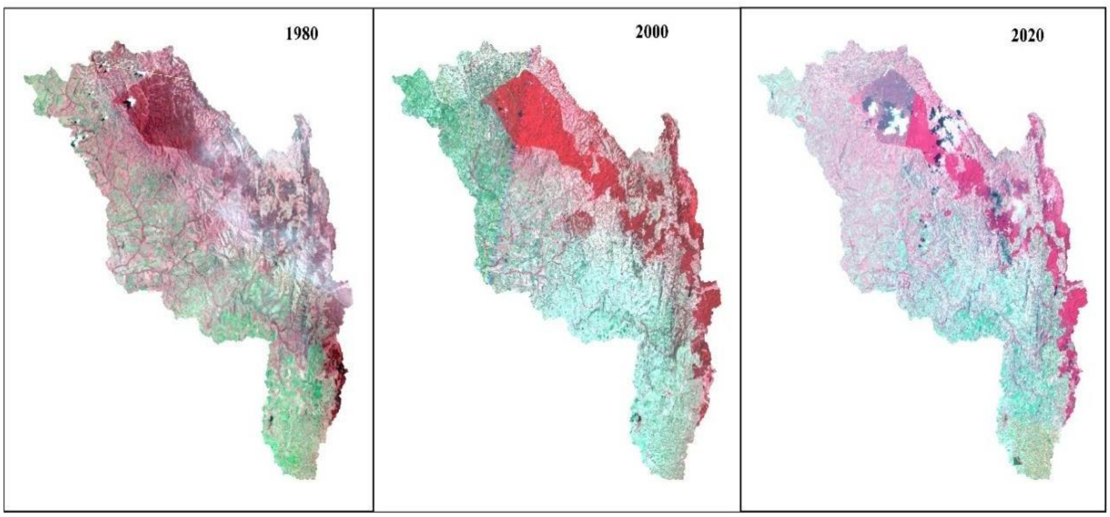

Figure 3.5: Extracted false colour images of the study area for the three periods. Source: Author

3.6.2 SWAT Modeling Process

The preliminary step was the definition of the slope, soil, LULC parameters and climatological data in databases (dbf tables). Each table had to be defined clearly using the nomenclature provided in the SWAT user's manual. The watershed delineation process was conducted and the watershed was extracted, then sub-divided into hydrological response units (HRU) and then the streams and the stream outlets were built using the DEM. The SWAT model generated 19 hydrological response units (HRU) from the sub-watershed (figure 3.6). In the creation of these HRUs, all the required data for hydrological simulations of the watershed were determined for each unit. Then for each land use, different soil types and slope associated with each were selected. For the LULC and soil definition, shape files were added in ArcGIS and linked to the SWAT database. To use the spatial datasets, "Look-up" tables were used to reclassify into SWAT compatible classes.

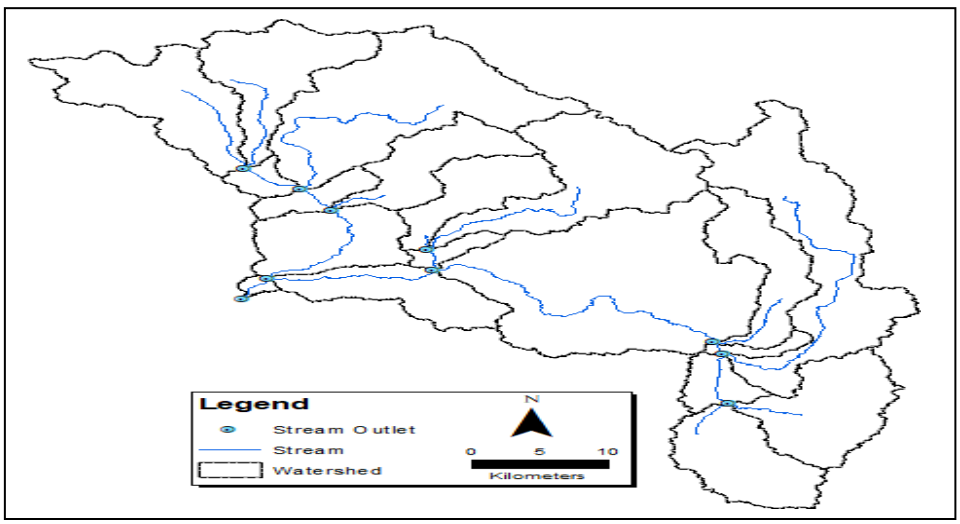

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Figure 3.6: The stream, HRUs and the stream outlets

Source: Author

SWAT Model Setup

The SWAT model was run from 1st January 1979 to 31st December 2013 on monthly basis. The SWAT model warm-up period was 3 years from1979 to 1981. The SWAT data used comprised of slope, soil, weather and LULC types. Three SWAT model scenarios were generated each using different LULC data. LULC data required for SWAT model were generated in ArcGIS. This applies to the LULC data for scenarios 2 (100% forest cover) and scenario 3 (100% agriculture). New shapefiles were generated by coding the entire basin shapefile dataset accordingly. The base scenario used the 1980 LULC types; while scenario 2 assumed 100% Montane Forest LULC type and scenario 3 assumed 100% agriculture LULC type (table 3.1).

Table 3.1*:* **The LULC scenarios used in SWAT model**

Scenario	Montane forest	Plantation forest	Bush-land	Agriculture	Wetland	Water
Base	17.60	1.69	28.61	46.50	5.57	0.04
2	100.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	100.00	0.00	0.00

SWAT output calibration was conducted in SWAT Calibration and Uncertainty Program (SWAT CUP). The SWAT CUP was developed for automatically computing sensitive model parameters. Sequential uncertain fitting ver-2 (SUFI-2) algorithm in the SWAT-CUP was used for this function. The readings from the calibrated model explained the uncertainties that were evaluated by the p-factor and the R-factor. The P-factor is the percentage of simulation within the 95% prediction uncertainty (95PPU). The SUFI-2 captures as many optimal simulations as possible that are within 95% prediction uncertainty (95PPU). Evaluation of the model performance, the coefficient of determination (R^2) statistic was applied. The R-factor is the average thickness of the

95PPU band divided by the standard deviation of the data (Abbaspour *et al.,* 2004, Abbaspour, *etal*, 2007). R^2 is a standard regression technique that is used to determine the strength of linear relationship between simulated and measured (observed) data. R^2 values ranges from 0 to 1 which represents the trend between the observed and simulated data, with the higher values indicating less error variance and better model performance. Values greater than 0.5, are considered acceptable (Moriasi, *et al*, 2007).

SWAT Model Calibration and Validation

A successful hydrological model requires calibration and sensitivity analysis (Abbaspour,2015) which is accomplished using observed data or application of regionalisation. In this study, observed river flow measurements were missing, necessitating application of regionalisation approach as described by Mengistu *et al*., (2019) for model calibration. This regionalization approach is based on the assumption that basins with identical characteristics have similar hydrological responses. The neighbouring basins of Sosiani River, Nzoia River and Kaptagat river donated the SWAT model calibration parameters. The specific study basin parameters for the exercise were sourced from Kibii *et al*., 2021; Odira *et al*., 2010 and Mainya 2017 and it included"Initial soil curve number for moisture condition" (CN), "Soil evaporation compensation factor" (ESCO), "Threshold depth of water in the shallow aquifer required for return flow to occur" (GWQMN), "Threshold depth of water in the shallow aquifer for Revap" (REVAPMN), "Ground water revap coefficient" (GWREVAP) and AlphaBF.gw. For parameters with more than one value, means were obtained and used. The calibration in the study catchment was accomplished using the ArcSWAT manual calibration helper.

3.6.3 Soil and Water Conservation Measures

The data for this objective was taken from the sampled paperless questionnaires. This data whichwas already coded was first cleaned to remove all the errors. The cleaned data was then run in theStatistical Package for the Social Sciences (SPSS) software as an analysis tool to obtain the results. The extent of soil erosion and the nature of slope on the farm were tested using Chi- square test.

3.7 Ethical Considerations

Cohen *et al.*, (2000) observe that it is important to observe ethics in research in order to maintain human dignity. Here are the considerations that were taken into account while undertaking the study.

The researcher first adhered to the principle of informed consent whereby the respondent were informed about the purpose and nature of the study.

The anonymity of individual respondents was preserved and the confidentiality of the data safeguarded so as to allow informed decision on participation. The respondents' privacy, confidentiality and honesty were maintained all through the study. Also plagiarism was avoided all through the an report writing stages attributes were given appropriately to all information from secondary sources, the findings were reported accurately and truthfully in order to avoid fraud.

3.8 LULC Accuracy Assessment

LULC accuracy assessment was carried out for the generated 2020 LULC. A total of 200 points were generated randomly using ArcGIS. The LULC at these points were compared with the LULC on the ground. The expected accuracy was determined by the following equation (Eastman, 2012):

$$EA = 1/(T + P)$$

Where;

EA-is the expected accuracy,

T-is the number of transitions in the sub-model

P-is the number of persistence classes

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0. Introduction

This chapter contains the results and discussions of the collected and analysed data from Moiben and Chepkaitit watershed. The results of the LULC types, the influence of LULC changes on the river discharge and the soil and water conservation measures that have been applied in the area, are discussed here. The chapter made use of the maps, tables, graphs and the discussion thereof.

4.1 LULC Change Results

The LULC types of the years 1980, 2000 and 2020 were processed from the Landsat satellite imagery and analysed in ArcGIS. The spatial data showed the kinds and extent of LULC in the watershed in the times under study (figure 4.1). The identified LULC types were montane forest, bushland, tea plantation, cropland, plantation forest, wetland, woodlot and urban area.

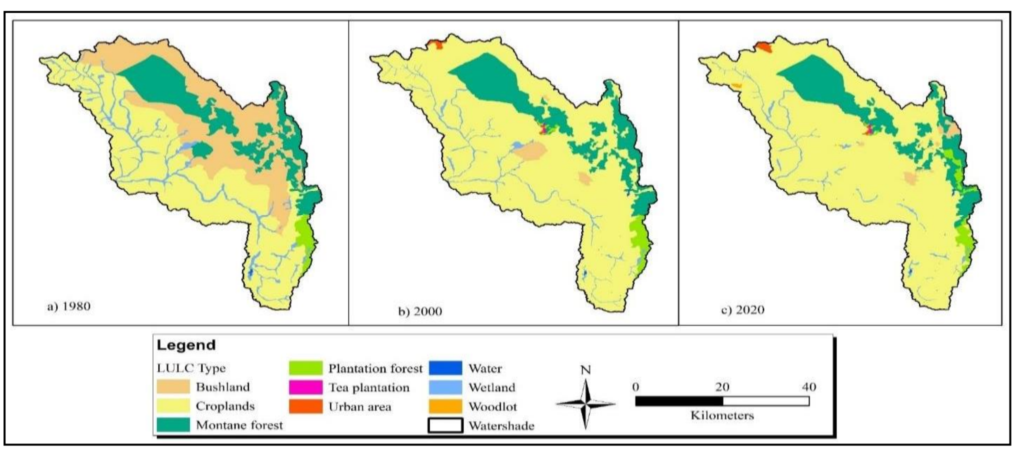

Figure 4.1: LULC in the years 1980, 2000 and 2020 in Moiben and Chepkaitit rivers watershed

Source: Author

The spatial LULC results indicate that the Bushland category has drastically reduced in 2000 and 2020, from the initial area of 619.18km^{2}to 30.17Km^2, after it dominated in the northern section of the watershed in 1980 with a corresponding expansion of Cropland. The Wetlands appear to have reduced with time from continuous to broken sections in 2020. Notably, new LULC that appeared in 2000 are the urban areas and Tea plantation. The Montane Forest spatial distribution is more or less the same unlike the Plantation Forest which is expanding to the northeast from southeast of the watershed. The LULC change trend was tabulated and the changes (in km^2) with time (table 4.1) were quantified. The results from the table indicate that there has been a significant change in the LULC in the watershed between 1980 and 2020. It is evident from the study that there was a reduction in the size of land under montane forest, bush land and wetland. Montane forest area reduced by 10% from year 1980 to 2000, and eventually decreased by 13% by the year 2020.

The wetland declined by 53% and 67% in the years 2000 and 2020 respectively, compared to thatof the year 1980. There is a very great change in the area of bush-land. It reduced by 94% from year 1980 to 2000 and by 2020 it had reduced by 95%. On the other hand, the area under water increased from 1980 to 2000 by 95% and then reduced to 82% in 2020.

In contrast, there was an increment in the size of land under crops (cropland), where in the year 2000, there was an increase of 67% and as at 2020, the increase was 69% compared to 1980. Additionally, it was also noted that the area under plantation forest has increased such that by 2000, it had increased by 9% and by 2020 it had increased by 32%, comparing it with the 1980 value. It was also noted that the tea plantation and urban areas which did not exist in the year 1980emerged in the year 2000 and their sizes had increased to 0.1% and 0.4% respectively in the year2020.

Table 4.1: ***The LULC changes between year 1980, 2000 and 2020***

	Years			Change		% Change	
LULC Type	1980	2000	2020	2000	2020	2000	2020
Crops	1006.23	1680.35	1701.55	674.11	695.31	67	69
Montane forest	380.81	340.99	330.79	-39.82	-50.03	-10	-13
Plantation forest	36.5	39.7	48.37	3.19	11.86	9	32
Tea plantation	0	1.61	1.99	1.61	1.99	100	100
Urban area	0	5.44	7.73	5.44	7.74	100	100
Woodlot	0	0	2.42	0	2.42	0	100
Water	0.84	1.65	1.54	0.8	0.69	95	82
Bush land	619.18	37.16	30.17	-582.02	-589.01	-94	-95
Wetland	120.47	57.14	39.48	-63.33	-80.99	-53	-67
Total	2164.06	2164.06	2164.06				

4.2 LULC Accuracy Assessment

Satellite image classification accuracy can be constrained by the image resolution used and insufficient fine details and also due to effects of unavoidable generalization (Oumer, 2009), thuserror will always be expected. Therefore, in order to ensure wise utilization of the LULC maps that had been produced and their related statistical results, the accuracy and error of the analysed outputs must be explained quantitatively.

LULC accuracy assessment was carried out for the generated 2020 LULC. A total of 200 points (as shown in table 4.2) were generated randomly using ArcGIS. The LULC at these points were compared with the LULC on the ground. The overall LULC 2020 classification from the calculation showed that for the entire watershed, the accuracy was 79.00% (that is, 158 out of 200 points were classified correctly). The accuracy for the different LULC types ranges from a low of70.00% (Urban area and Woodlot) to a high of 84.48% (crops).

Table 4.2: LULC accuracy assessment table

		LULC Type on the Ground									
	LULC	**Crops**	**Montane Forest**	**Plantation Forest**	**Tea Plantation**	**Urban Area**	**Woodlot**	**Water**	**Bush land**	**Wetland**	**Total**
LULC Type from Classified	**Crops**	49	0	1	1	0	0	0	0	0	51
	Montane forest	0	25	4	1	0	0	0	1	0	31
	Plantation forest	0	5	19	0	0	1	0	0	0	25
	Tea plantation	4	1	2	10	1	1	0	1	0	20
	Urban area	1	0	0	1	7	0	0	0	0	9
	Woodlot	1	0	0	0	0	7	0	1	0	9
	Water	0	0	0	0	0	0	10	0	3	13
	Bush land	3	1	1	1	2	1	0	15	0	24
	Wetland	0	0	0	0	0	0	2	0	16	18
	Total	58	32	27	14	10	10	12	18	19	200
	Accuracy (%)	84.48	78.13	70.37	71.43	70.00	70.00	83.33	83.33	84.21	

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4.3 LULC Discussions

The study area is thus seen to have witnessed a reduction in the montane forest, bush land and wetland. This reduction could be attributed to deforestation to create land for crop farming, tea plantation and creation of urban space. It is thus seen that deforestation is taking place in favour of other land uses such as tea plantation, urban centres and crop land. The area has seen the introduction of urbanization and tea plantation in the area, whereas at the same time the montane forest has reduced. This then implies that there is increased deforestation in the region from the year 1980 to 2020. The plantation forest could be linked to the initiative by the government urgingpeople to plant trees and at times giving them incentives to do so. The study also indicated a progressive reduction of wetland from 120.5km^2 in 1980 and to 39.5 km^2 in 2020. And this is an indication that most of the wetlands have been reclaimed for agricultural purposes.

The study in Moiben and Chepkaitit rivers' watershed have also indicated from the analysis that the region has been subjected to a gradual process of conversion to other LULC types due to high population pressure. The period of 1980 to 2020 indicated a significant change in LULC types. The land use change is a global issue currently, where agricultural production is either achieved through intensification or by conversion of more lands for farming (Mwangi, 2018). It is indicativethat settlement and cultivation expansion are imminent (Kashaigili, *et al*., 2010). The universal influence of the economic crisis is seen to be the motivating principal for the changes on LULC types (Butt, *et al*, 2015). Ngeno (2016) also in a study in Nyangores catchment affirms that the forest has been reduced and replaced by farm land expansion. These changes have also been noted from the results of the study that intensification of agriculture is taking place and the crop land has increased from 1006.24km^2 in 1980 to 1701.55km^2 in 2020. The Nyayo Tea Zones Corporation aswell introduced tea farming in the region, which increased from 1.61 km^2 in 2000 to 1.99 km^2 in 2020. At the same time, loss of forestation and loss of bush land have resulted. While the crop land is increasing, the bush land, forest and wetlands are reducing. This is an indication that deforestation is being carried out in the region to create room for cultivation. Further, the wetlands also have been reclaimed to create room for agriculture. It means then that the population has increased (the market) therefore, there is need to produce more food, and this creates pressure which drives LULC changes as observed by Cheruto, *et al*, (2016). It thus holds from the results that loss of forest is triggered by some factors and these factors are both direct and indirect.

The direct drivers to the loss include illegal logging of timber, production of charcoal, excessive harvesting of firewood and building poles, forest fires, overgrazing, farming and forest excisions for settlement (Kenya water Towers agency 2020; Ministry of forest and wildlife 2013; Rotich and Ojwang, 2021). The indirect drivers on the other hand include; increased demand for agricultural land for food due to increased population growth; limited institutional capacity for effective forest management and monitoring; integrity issues among some officials in charge of forest management and poor implementation of existing forest and land use policies (Kogo *et al*, 2019; Ministry of Environment and Forestry, 2020; Rotich and Ojwang, 2021).

According to Brink and Eva (2009) Africa sub-Sahara region lost about 16% of its forest and 5%of its woodland and bush land between the year 1975 and 2000, while agricultural land increasedby 55%. The grass land as well converted to cropland at a very high rate. The vast and rapid expansion of cultivated crop land is linked to population growth in the region. The studycorroborates with that of Odawa and Seo (2019) who found out in their study that population growth resulted in massive land use and land cover changes in the water tower, as farmers residingaround the buffer zone expanded their agricultural lands through their extensive and dynamic agricultural activities. A land use and land cover change analysis in East Africa also showed that there is an increase in the cropland area at the expense of the natural forest, grass land and woodland and it resulted in a large scale reduction of the woody vegetation classes.

4.4 Impacts of LULC Change on River Discharge

Results of modelled river discharge (table 4.3) are presented on monthly basis for the entire periodunder study. The river discharge was not uniform throughout the year having minimum of 15.41cm/s in the month of February and maximum of 224.31cm/s in the month of August. The lower values indicated the dry months while the higher values indicated the wet months.

Table 4.3: ***River discharge (cm/s) for the three LULC scenarios***

Base Scenario		**Scenario 2**	**Scenario 3**	**Scenario 2 % Change**	**Scenario 3 % Change**
Jan	24.53	30.50	21.11	24.36	-13.92
Feb	15.41	17.91	14.30	16.17	-7.21
March	15.95	15.67	16.81	-1.75	5.42
April	58.62	44.83	70.09	-23.51	19.57
May	116.36	100.77	128.50	-13.40	10.43
June	144.57	133.95	153.05	-7.35	5.86
July	187.62	180.47	194.18	-3.81	3.50
Aug	224.31	223.69	224.75	-0.28	0.20
Sept	165.96	184.79	152.11	11.35	-8.35
Oct	113.20	128.74	102.02	13.73	-9.88
Nov	80.71	90.38	74.35	11.97	-7.88
Dec	44.72	54.41	38.36	21.66	-14.23

The SWAT-CUP calibration yielded the coefficient of determination (R^2) of 0.89 (figure 4.2) indicating a very good SWAT model performance. According to Moriasi, *et al*, (2007), R^2 is a standard regression technique that is used to determine the strength of linear relationship between simulated and measured (observed) data. R^2 values ranges from 0 to 1 which represents the trendbetween the observed and simulated data. R^2Values greater than 0.5, are considered acceptable. This is a confirmation that the hydrological processes were realistically modelled in this study.

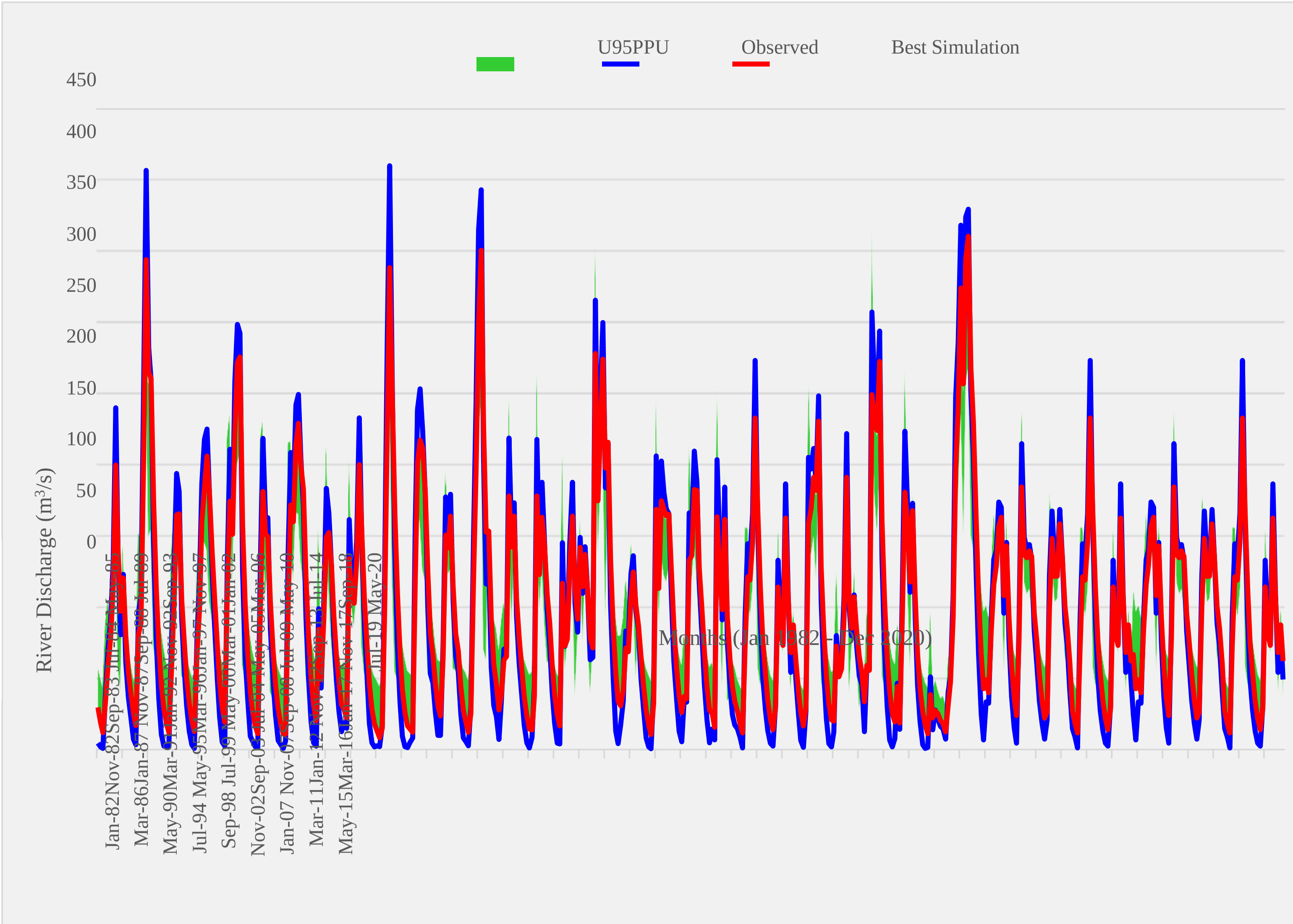

Figure 4.2: Monthly time series of simulated and observed river discharge rate (in cubic meters per second) for Chepkaitit and MoibenRivers' watershed.
Source: *Author*

Scenario 2: 100% Forest LULC

The stream hydrograph is more or less the same as the base scenario with differences in the rate of water flow. The stream-flow varies from the base scenario in both positive in January, February and September – December while it was negative in March to August (figure 4.3). In the month ofJanuary, the stream-flow rates increased by 24.36% while the maximum decrease is in the month of April by 23.51%. This means that the presence of trees reduces the surface water run-off by increasing retention time thereby encouraging water infiltration.

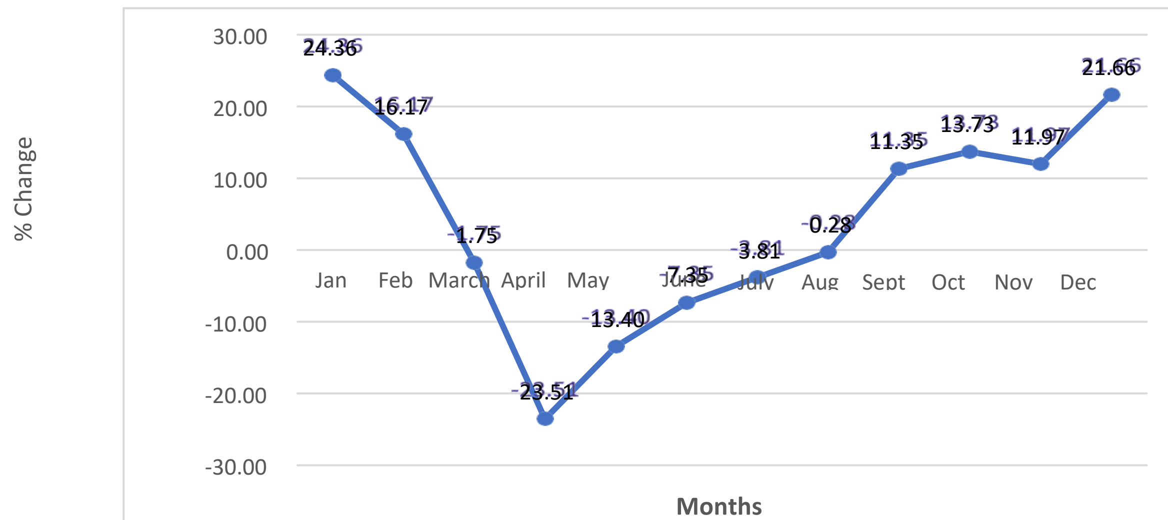

Figure 4.3: The percent river discharge change for scenario 2 LULC

Source: Author

Scenario 3: 100% agriculture LULC

In this scenario, the stream-flow varies from the base scenario in flow rate though the hydrographpattern is identical. The percentage change is positive between March and July while the negative changes occur both in January, February and September – December (figure 4.4). In the month of December, the stream-flow rates decreased by 14.23% while the maximum increase is in the month of April by 19.57%. This means that the agricultural land generally encourages excessive surface water run-off by reducing retention time thereby discouraging water infiltration.

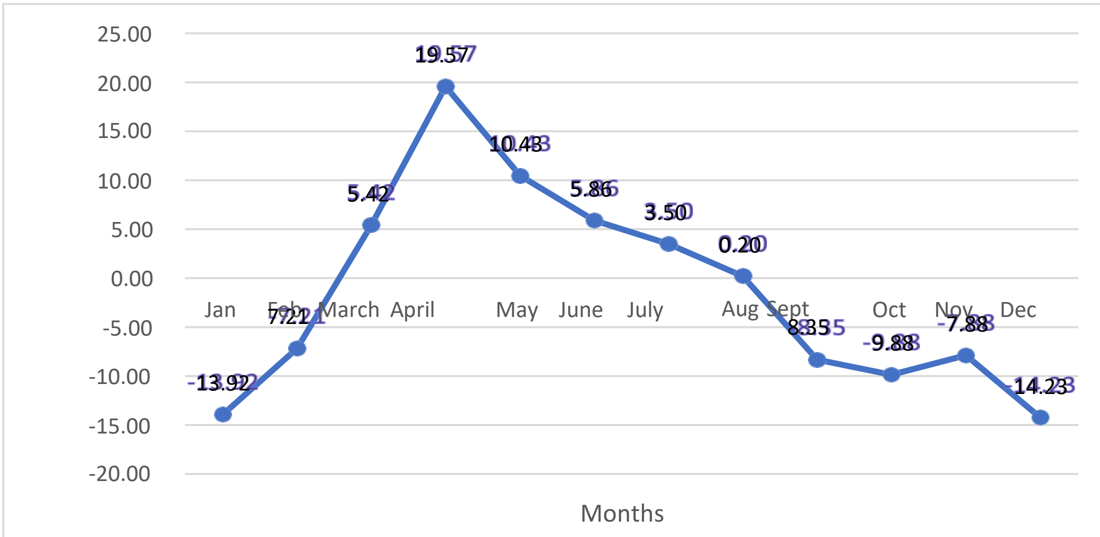

Figure 4.4: The percent river discharge change for scenario 3 LULC

Source: Author

4.5 Discussions of Impacts of LULC change on river discharge

The results of the SWAT model as from the above scenarios indicated that the river discharge is different for different months due to the difference in the seasonal weather pattern and the different LULC scenarios. The simulations when the forest was assumed to be 100% showed that the river discharge during the wet months was very low compared to the dry months. This means that when the watershed is highly forested, the river discharge is not affected by run-off that occurs during rainy season. It thus holds that forest prevents the excessive run-off. The forest vegetation increases water retention time thereby allowing infiltration. This study then agrees with what other researchers have observed in other regions. Andreassian (2004) indicates that the increase of the forested area causes a decrease of the maximum peak flow and an increment in the base flow discharge values in a study in Russia. These changes could be attributed mainly to deviations in evapotranspiration, surface roughness and water infiltration rate in the soil. At 100% agriculture on the other hand, it showed very high river discharge during the rainy season. The reason for thisis due to lack of forest to prevent excessive run-off. The simulated scenarios then agree with the theory that forests are sponge-like, in that it holds water during the rainy season and releases it during the dry period. Deforestation according to Bonan, *et al*., (2004), changes the hydrological, geomorphological and biochemical states of streams. Changes in vegetation generally results in increased discharge because root density and depth have been reduced by agricultural activities (Canadell, *et al.,* 1996). Forest floors have leaf litter and porous soil which easily accommodate intense rainfall as infiltration takes place slowly until the soil is saturated. The trees funnel water into the underground aquifers where it will be stored to supply rivers during drought. Tree leavesalso hold some rain water that evaporates directly to the atmosphere. Run-off is thus controlled bythis nature of trees and therefore soil is protected from being eroded into the rivers. It holds therefore that deforestation will highly lead to increased river discharge during the rainy season and reduced river discharge during the dry weather seasons (Liu, *et al*., 2015).

Land use was observed to influence the soil hydrological properties which are measured by the movement of water in the soil and compaction of soil interferes with the movement of water, increases soil bulk density and reduces hydraulic conductivity and infiltration (Nzitonda, *et al*, 2019). The least river discharge for agricultural land during the dry period was due to the low levels of infiltration and excessive runoff during the wet season. The low infiltration rate is due to compaction of lower soil horizons resulting from continuous tillage of agricultural land (Ankeny, *et al*, 1990). This compaction also increases the bulk density of the soils (Logsdon, *et al,* 1990) and thus will determine the run-off volume. The scenario for the agricultural land indicates that water interception in the sub-catchment is low and thus meaning less time for infiltration. This is mainly caused by decrease in forest cover and increase in croplands therefore reducing rain water interceptions leading to increase in surface run-offs in the sub-catchment (Olang', 2009). Because of the low levels of infiltration, the replenishment of the groundwater was very low and thus reduced river discharge during the dry seasons. Forests are less compacted and that is why they have high infiltration rates and high hydraulic conductivity compared to other land uses (Nzitonda,*et al*, 2019).

4.6 Soil and Water Conservation Measures

In the watershed region under study, the sampled population comprised of 46% Males and 54% Females as shown in table 4.4.

Table 4.4*: Gender distribution*

Gender	Frequency	Percentages (%)
Male	100	46%
Female	119	54%

From the results, majority of the respondents were in the age bracket of 18-30, comprising a percentage of 32% while the age bracket of >61 constituted the least percentage. The rest are shown in the table 4.5. Most of the respondents between age 18 to 30 years were single mothers and housewives whose husbands went on errands. The results of the study reveal that people living within the area of study are farmers and practice different agricultural practices. From table 4.6, majority of the respondents practiced Mixed Farming, 87% with the least of them practicing livestock keeping, the rest are as shown in the table.

Table 4.5*: Age Group Distribution*

Age Group	Frequency	Percentage (%)
18-30	69	31.40%
31-41	67	30.59%
41-50	68	31.01%
51-60	12	6%
>61	3	1%
TOTAL	219	100%

Table 4.6: Agricultural activities in the study area

Agriculture Practice	Frequency	Percentages (%)
Crop Production	20	9%
Livestock Keeping	8	4%
Mixed Farming	191	87%
Total	**219**	**100%**

Based on the study in the watershed, soil erosion is influenced by farming and especially land use. Different measures have thus been applied to conserve the soil as presented in table 4.7. From the output, majority of the respondents, 41%, chose terraces as the main soil conservation measure, followed by planting trees at 25% with the least being practicing strip cropping, the rest are as shown in the table.

Table 4.7: ***Measures applied to conserve the soil and water in the study area.***

Soil Water Conservation Measures	Frequency	Percentages (%)
Gabions	34	15.53%
Planting Trees	54	24.66%
Practicing Minimum Tillage	24	10.96%
Practicing strip Cropping	18	8.22%
Terraces	89	40.64%
Total	**219**	**100%**

The results of the hypothesis test using chi square yielded a *p* value of 0.0001 (table 4.8) which showed that there was a significant relationship between the slope of the land and the extent of soilerosion and thus the null hypothesis was rejected. The results of the study thus indicate that the nature of the slope of land greatly influence the rate of erosion.

Table 4.8: Chi-square analysis of nature of farm slope and extent of soil erosion

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	100.564	9	.0001
Likelihood Ratio	45.282	9	.0001
N of Valid Cases	219		

The rate of soil erosion in agricultural lands, especially croplands, is higher than in forested lands. This is because agricultural practices such as tillage, monoculture, and overgrazing remove the protective cover of vegetation, leaving the soil exposed to the elements. Additionally, agriculturalland is often located on steeper slopes, which increases the risk of erosion. As a result, soil erosion can lead to a loss of productivity, water quality problems, and environmental degradation. Specificexamples of how agricultural practices can lead to soil erosion include:

Tillage: Tillage breaks up the soil, which exposes it to the wind and rain. This can causethe soil to wash away or be blown away.

Monoculture: Monoculture is the practice of growing the same crop in the same field year after year. This can lead to a build-up of pests and diseases, which can damage the soil and make it more susceptible to erosion.

Overgrazing: Overgrazing removes the vegetation that helps to hold the soil in place.

This can lead to the formation of gullies and other erosion features in many agricultural lands, majorly croplands, the rate of erosion was higher compared to forestedlands. In steep slopes where agriculture was carried out experienced the highest rate of erosion. In gentle slopes with agriculture, the rate of erosion was moderate. The areas where trees were planted generally had very low to no erosion. This means that forested areas have good advantage of holding the soil together and in preventing run-off from carrying away the soil.

It was also noted that across the watershed there were some regions which were initially set to be forestland but on the contrary, there was some encroachment onto it by some settlers who resided in the region. The residents practised agriculture and this led to increased erosion along the watershed. For instance, the regions around Cherangani, Kapcherop and Chebororwa were over exploited by the settlers and the forest was reduced for food production. Erosion then as a challenge along the watershed has called for certain management practices to be applied unto it. Several soil and water conservation and management measures were employed to restore the degradation of soil in the region. Measures such as terracing, use of gabions, tree planting and strip cropping and minimum tillage were used in the region to curb and/or control soil erosion as shown in table 4.7. Gabions, which made use of stones, were used in more steep lands and generally sloppy land because gabions reduce the run off speed such that by the time it is setting on the agricultural land, the impact will be minimal. Terraces were also used majorly in the region as they assist in retaining the soil which is loaded in the runoff. The vegetation in the terraces assists in holding the soil andpreventing much loss of soil to low-lands.

Soil is a sink of plant nutrients and will determine what an ecosystem can produce (Lal & Pierce, 1991; Hati, *et al.*, 2013). Soil properties are the major governing factors in erosion processes in the landscape, which majorly is affected by soil and water management interventions (Wei, *et al.*, 2012; Abegaz, *et al.*, 2016). The dynamics of soil properties always depend on land management practices and the inherent properties of the soil (RE, 2013).

Soil conservation and control is one of the major issues in dealing with agricultural lands currently. The increased need for agricultural land has led to reduction of other natural resources such as bushes and forests, thus it somehow has led to introduction of land degradation. To mitigate soil degradation then, Soil water conservation (SWC) measures are said to be the principal component for agricultural watershed management. SWC measures affect surface roughness and soil cover, thus aid potentially in soil retention against raindrops and running water (Asmare, *et al*., 2020). Soil erosion majorly occurs when there is surface runoff. Surface runoff occurs when the rainfall exceeds the infiltration rate of the soil. Run off speed and loads are generally influenced by factors such as topography, vegetation, infiltration rates and soil storage capacity. It also holds that the surface roughness and cover of the soil affect the surface runoff. This is why the forested land did not undergo erosion easily like the crop land. Terraces and gabions also provided the surface roughness on the bare ground that helped is controlling the surface runoff, and thus the soil erosion.

These measures divide the slopes in a landscape and hence reducing the quantity and speed of surface runoff by increasing the time of concentration (Belayneh, *et al*., 2019). The measures prevent loss of the thin fertile topsoil by enabling trapping of the eroded materials, thus in the long run reduce sediment production into the streams. A study by Asmare, *et al*., (2020) indicated that terraces, as the physical SWC measures, reduce surface run-off by about three times. Mekonnen, *et al*, (2017) also report that SWC barriers, for example terraces, have significant role to trap sediment within the catchment by decreasing soil erosion and enhancing the sedimentation rate within a catchment through channel dis-connectivity. Additionally, it was found out that planting of vegetation on dike terrace was important in controlling soil erosion compared to farming on slope land (Shen, *et al*, 2010 and Li, *et al*, 2011). Plant roots hold the soil in place and prevent thesoil from collapsing during rains (Dong, *et al*, 2015).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENTATIONS

5.1 Summary

This study was aimed at examining the effects of LULC on monthly stream flow in Moiben and Chepkaitit Rivers' watershed. The specific objectives were; to analyze LULC in the watershed, to model the influence of LULC on rivers' water discharge and to establish the types of water and soil conservation measures in the watershed.

Quantitative research techniques were employed in the study. Remote sensing and GIS techniqueswere used in the study to determine land use land cover changes over a three-time periods of twenty years intervals. The LULC changes were processed from remotely sensed images obtained by Landsat satellite series. Three satellite images of the years 1980, 2000 and 2020 were acquired and processed. The processing of these images was done in ArcGIS to produce maps of the study area within the period of study. The land use and land cover types in the study area were montane forest, bush land, tea plantation, cropland, plantation forest, wetland, woodlot and urban area. Using the SWAT hydrological model, the simulation of effect of LULC changes on the river discharge was conducted. The interface of ArcSWAT was used for the setting, parameterization and running theSWAT model.

The results showed that there were land use and land cover changes within the watershed environment. The forest land, watershed and bush land reduced; there was an introduction of tea plantation and urban area and there was an increase in cropland. These changes in the LULC resulted in changes of the stream flow discharge rate. The rate of flow during the rainy season wasvery high, while in dry period, the rate of flow was extremely low. It was also established that several soil and water conservation measures were employed in the area. The steepest areas applieduse of gabions, tree planting and terraces.

5.1.1 Land Use and Land Cover Changes

Within the time of study, 1980, 2000 and 2020, it was concluded that there have been significant changes on the LULC along Moiben and Chepkaitit Rivers' catchment. Deforestation and reduction of bush land and wetland had taken place along the watershed. Reduction of forest and bush land was 13% and 95% respectively. Cultivation on the other hand was replacing these landcovers. Cultivated land had increased by 69% in the year 2020 as compared to what it was in 1980.

5.1.2 Impacts of LULC Change on River Discharge

Modeled data sets using the SWAT-CUP under two scenarios, scenario 2 (100% forest LULC type) and scenario 3 (100% agriculture LULC type), showed that LULCCs will impact in the riverdischarge. The LULC changes along the watershed led to changes in the river flow discharge rates.The change in land use from forest land to agricultural land led to increase in runoff and thus increasing river discharge during the wet months. During the dry months, the flow was very low in agricultural lands because the underground aquifers were not replenished during the wet monthsdue to excessive runoff. Forested areas on the other hand were opposite to that of agricultural land.Under this situation, infiltration occurred during the rainy season and thus the river discharge was normal.

5.1.3 Soil and Water Conservation Measures

Changes in LULC have led to challenges of soil and water conservation. To over-come this challenge, soil and water conservation measures were applied. A measure that was majorly employed in the area was use of terraces. Farmers majorly made use of this technique as it assisted in reducing the speed of runoff that otherwise could have carried a lot of soil. Planting of trees was also employed as a technique by some farmers and it aided in controlling soil erosion. Minimum tillage, use of gabion and strip cropping were also used as other measures. These soil and water conservation, measures aided in controlling surface runoff by increasing the time of concentration and reducing the speed of running water. These measures have also become very important in improving the sediment trapping capacity of the land.

5.2 Conclusions

It was noted that there were significant LULC changes in the Moiben and Chepkaitit rivers' watershed. Large sections of the montane forest land had been converted to agricultural land especially with introduction of tea farming and urban area. Plantation forest also increased while wetland was also noted to have decreased in the study area. The clearing of tree plantation and the increment in cultivated land has resulted in severe soil erosion in the area.

The condition of soil and water resources is closely related to human population density, resource extraction and activities such as intensification of agriculture. The increased needs by human populations have led to the alteration of these natural landscapes into urban settlements, agricultural systems (crops and livestock grazing) for food production, and harvest of natural resources (timber). Therefore, protecting these resources against degradation is vital for maintaining healthy soils for food production, provision of regenerative ecosystem services for clean water and air resources and maintenance of diverse landscapes.

It is also worth noting that the type of LULC in an area coupled together with the nature of the slope of land greatly influence the rate of erosion. Cultivation on the steep slopes then should be under taken with some serious measures such as use of terraces, gabions, minimum tillage and tree planting. These measures are fundamental for control of soil erosion and thus the conservation thereof.

The findings and conclusions of this study then will provide useful information that will assist in decision making efforts of land use planning and water resource management. Additionally, the integrated approach developed in the study will also be applied to other watersheds and particularlythose that have experienced rapid LULC change.

5.3 Recommendations

The study makes the following recommendations:

a) The current LULC patterns in the study area are negatively affecting the river discharge. The study recommends that deforestation should be controlled to mitigate this impact. Specifically, the riparian vegetation, which is the vegetation that grows along the banks of rivers, should be conserved. This is because riparian vegetation plays an important role in regulating river flow, preventing erosion, and providing habitat for fish and other wildlife. The study also recommends that the local communities, environmentalists, and the Kenya Forest Service (KFS) should work together to conserve the riparian vegetation. The local communities can play a role by planting trees along the river banks and by avoiding activities that could damage the vegetation. The environmentalists can provide technical assistance and advocacy, and the KFS can enforce the laws that protect the riparian vegetation. Further, the laws that govern forest resources should be revisited and that thorough routine checks be done to ensure that they are being enforced. This is important to ensure that the riparian vegetation is protected and that the river discharge is not further affected. Some specific actions that can be taken to control deforestation and conserve riparian vegetation include:

Enforce existing laws and regulations: The government should enforce existing laws and regulations that protect forests and riparian vegetation. This includes punishing those who illegally deforest or damage these areas and providing incentives to protect and conserve these areas.

i) Create and enforce protected areas: The government should create and enforce protected areas that are off-limits to deforestation and other damaging activities. Promote sustainable forest management: The government should promote sustainable forest management practices, such as selective logging and replanting.

ii) Provide financial incentives for forest conservation: The government can provide financial incentives for forest conservation, such as subsidies for planting trees and taxbreaks for landowners who conserve forests.

iii) Educate the public: The government and other stakeholders should educate the public about the importance of forest and riparian conservation. This can be done through school programs, public awareness campaigns, and the media.

iv) Partner with local communities: The government should partner with local communities to develop and implement conservation plans that are tailored to the specific needs of the study area.

b) Forests and catchments are essential for our well-being. They provide us with clean air and water, regulate our climate, and support biodiversity. However, they are under increasing threat from deforestation, pollution, and climate change. Authorities can play a key role in ensuring the conservation of forests and catchments. Some of the key actions to be undertaken may include the following:

1. Create and enforce laws and regulations to protect forests and catchments. This can comprise laws that ban deforestation, regulate pollution, and protect endangered species.

2. Provide financial incentives for forest conservation. This could include subsidies for planting trees, tax breaks for landowners who conserve forests, and payments for ecosystem services.

3. Support community-based forest management. This gives local people a stake in the conservation of forests and helps to ensure that they are managed sustainably.

4. Invest in research and development. This could help to develop new technologies for forest conservation, such as sustainable logging practices and methods for restoring degraded forests.

5. Raise awareness of the importance of forests and catchments through education programs, public awareness campaigns, and the media.

6. Other important specific strategies that authorities can take to ensure forest and catchmentconservation includes the following:

i) Establish protected areas: Protected areas are areas of land or water that are legally protected from human activities. They can be used to conserve forests and catchments, as well as other important natural resources.

ii) Support sustainable forest management: Sustainable forest management is the practice of managing forests in a way that meets the needs of both people and the environment. This can be done through practices such as selective logging, replanting, and fire management.

Promote agroforestry: Agroforestry is a system of farming that integrates trees with crops and/or livestock. It can help to conserve forests and catchments by providing shade for crops, reducing soil erosion, and improving water infiltration.

Educate the public: Education is essential for raising awareness of the importance of forest and catchment conservation. Authorities can support education programs that teach people about the benefits of forests and catchments and how they can be conserved.

Partner with local communities: Local communities often have a deep understanding of the forests and catchments in their area. Authorities can partner with local communities to develop and implement conservation plans that are tailored to the specific needs of the area.

c) Furthermore, farmers should be encouraged to practice conservation agriculture, with emphasis in conservation agriculture such as agroforestry and zero tillage. Conservation agriculture is a set of farming practices that aim to protect the soil and improve itsproductivity. It includes three main principles:

Minimum tillage: This means that the soil is disturbed as little as possible, which helps toprotect its structure and organic matter content.

Maximum soil cover: This means that the soil is always covered with vegetation, which helps to protect it from the sun, wind, and rain.

Crop rotation and/or association: This means that different crops are grown in the same field in different years or that different crops are grown together in the same field. This helps to prevent the build-up of pests and diseases and to improve the soil's fertility.

Agroforestry is a system of farming that integrates trees with crops and/or livestock. It has many benefits, including:

Increased soil fertility: Trees help to improve the soil's structure and organic mattercontent, which makes it more productive.

Reduced soil erosion: Trees help to protect the soil from the wind and rain, which reduceserosion.

Improved water infiltration: Trees help to improve the infiltration of water into the soil,which helps to prevent flooding and waterlogging.

Increased biodiversity: Trees provide habitat for a variety of plants and animals, whichhelps to improve the overall health of the ecosystem.

Reduced pests and diseases: Trees can help to attract beneficial insects that prey on pests,which can help to reduce the need for pesticides.

It is also important to note that conservation agriculture and agroforestry can be used together asfollows:

i) Farmers can plant trees on their fields to provide shade for their crops and to protect the soil from erosion.

ii) Farmers can intercrop trees with their crops, which can help to improve the soil's fertility and to reduce the need for herbicides.

iii) Farmers can establish silvopasture systems, which combine trees, crops, and livestock. Thiscan help to improve the soil's health and to provide a more diverse source of food for bothhumans and animals.

5.4 Recommendations for Further Research

During the study period, the wetlands continued to decrease and the total depletion accounted for 67% which needs further rigorous investigation to investigate more reasons behind this widespreaddepletion besides excessive deforestation. The research can focus on the impact of climate change on forest ecosystems: Climate change is a major threat to forests, and research is needed to better understand its impact. This could focus on how climate change is affecting forest growth, productivity, and composition.

The role of forests in mitigating climate change: Forests play an important role in mitigating climate change by absorbing carbon dioxide from the atmosphere. Research is needed to better understand how forests can be managed to maximize their carbon storage potential. The emphasis here should be on developing new forest management practices, such as planting trees that are more efficient at storing carbon.

The economic value of forests: Forests provide a variety of economic benefits, such as timber, non-timber products, and ecosystem services. Research is needed to better understand the economic value of forests. This will look at developing methods for valuing the non-market benefits of forests, such as their role in regulating water quality and providing recreation opportunities.

The social dimensions of forest conservation: Forest conservation often involves the participation of local communities. Research is needed to better understand the social dimensions of forest conservation. This should bring out the needs and priorities of local communities, and on developing ways to involve them in forest management decisions.

The role of technology in forest conservation: Technology can play a role in forest conservation, such as by providing tools for monitoring forest health and by developing new forest management practices. Research is needed to better understand how technology can be used to conserve forests. The focus here should be on developing new technologies, such as drones and satellite imagery that can be used to monitor forests.

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APPENDICES

Appendix I: Letter of Introduction

Dear respondent,

I am Abigael Chepkurui, a master's student from Moi University. I am conducting research on impacts of land use land cover changes on Chepkaitit and Moiben rivers Kenya. The purpose of this study is purely academic. Kindly fill the questionnaire as truly and honesty as possible. Theinformation given will be highly confidential.

Thank you.

Matters to Note

The information given in this questionnaire will be held in strict confidence and will be usedonly for the purpose of the study

If any of the questions may not be appropriate to your circumstances, you are under noobligation to answer them.

Appendix II Questionnaire

Section A: Household Characteristics

1. Select your age bracket from the choices given.

Age(years)	(tick)
1. 18-30	
2. 31-45	
3. 41-50	
4. 51-60	
5. 61 and above	

2. Marital status

i) Single ii) married, iii) widowed iv) separate v) divorced

3. What is your main source of income?

Source of income	(tick)
1.Farming	
2.Employed	
3.Business	
4.timber/ firewood/ furniture	
5. Others, specify	

4. What is the size of your land (in acres)?

5. Do you practice agriculture?

6. What type of agriculture do you practice – (Livestock keeping, Crop planting, Mixedfarming)?

7. Which livestock?

8. Which major crops do you plant?

Section B: Soil and Water Conservation and Management Practices

9. What type of soil exists in your farm? (Tick appropriately)Loam ( ) clay ( ) sand ( )

10. What is the nature of the land slope?

Too sloppy ( ) sloppy ( ) gentle ( )

11. . Have you experienced soil erosion in your farm?

Yes ( ) No ( )

12. What is the extent of soil erosion? (Options: minimal, medium, massive)

13. What are the major contributors of soil erosion on your farm? Rate as using the following 1)minor 2) medium 3) major

Factor	1	2	3
Lack of cover crop			
Over cultivation			
Overgrazing			
Deforestation			
Rainfall			
Other 1 (State)			
Other 2 (State)			

14. Do you practice any soil and water conservation measures? (Yes, No)

15. Which soil and water conservation measures have you implemented? (List from the mostto the least applied)

16. What conservation measures have been put in place to curb soil erosion in the region?

Appendix III: Krejcie and Morgan Table

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size. *S* is sample size.

Source: Krejcie & Morgan, 1970