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Assessment of effects of deforestation on spring's water production: A case study of Nuu/Mutaitho Hills Springs in Kitui County

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DECLARATION

This thesis is my own original work and has not been submitted for examination in any other university

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ABSTRACT

This study is focused on the assessment of the effects of deforestation on springs found in Nuu and Mutaitho hills in Kitui County. Deforestation is manifested by clearing of dry land forests on a massive scale. Springs in Nuu and Mutaitho hills originate from groundwater aquifers and are essentially formed on hillsides and valley bottoms that intersect groundwater flow at or below the local water table. The main objective of the study was to determine the main causes of decline in spring discharges in Nuu and Mutaitho Hills catchment. This was achieved through establishment of the relationship between spring discharges, rate of deforestation, and rainfall variability. The study also involved determination of the impacts of decreasing spring discharges and examination of the perceptions of the local communities on the causes of decline in spring discharges. The study methodology involved collection of data in the field using questionnaires and field based observations. Field data was supplemented with data that was obtained from archival sources e.g spring discharges and rainfall data. The data was analyzed using the Statistical Package for the Social Sciences (SPSS), Geographical Information system (GIS) and various statistical tools in Microsoft Excel package. The result of the study shows that annual rainfall is showing significant variation while the spring discharges over the years has been decreasing drastically. Springs discharge is decreasing at a rate of 30%. Rainfall variability in the study area has changed within the study time from 800mm/year to around 700mm/year. The LANDSAT data showed that the forest /vegetation cover has decreased by almost 40% as the forest in 1963 was at 10% and the current forest cover is about 6% within the study area. The main cause of the decrease of the forest cover from the study is mainly anthropogenic activities. The study recommends more awareness campaign focusing on conservation of the Nuu hills forests and enforcement of regulations focused on the protecting forest resources.

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LIST OF ABBREVIATIONS

WHO	World Health Organization
WARMA	Water Resources Management Authority
UTM	Universal Transverse Mercator (Coordinate system)
USAID	United States Agency for International Development
UNICEF	United Nations Children's Educational Fund
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
UN	United Nations
TAWSB	Tanathi Water Services Board
SPSS	Statistical Package for the Social Sciences
SLM	Sustainable Land Management
SEKU	South Eastern Kenya University
SDGs	Sustainable Development Goals
MWI	Ministry of Water and Irrigation
MODIS	Moderate Resolution Imaging Spectroradiometer
KMD	Kenya Metrological Department
KLA	Kenya Land Alliance
KEBS	Kenya Bureau of Standards
GPS	Global Positioning System
GoK	Government of Kenya
GIS	Geographical Information System
FAO	Food and Agriculture Organization
DEM	Digital Elevation Model
ASALs	Arid and Semi-Arid Lands
KFS	Kenya Forests Services
NEMA	National Environment Management Authority
KEFRI	Kenya Forestry Research Institute
WSB	Water Services Board
NGO	Non-governmental organization

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 Introduction

This study entails the assessment of the effects of deforestation on semi-arid lands springs found in Kitui County. The study was specifically carried out in Nuu and Mutaitho hills which are located in Nuu Ward, Mwingi Central Sub- County. The study area occurs in Kitui County in the south eastern region of Kenya that occupies surface area of approximately 30,496 Km^2. The study area comprises two hills, namely Nuu and Mutaitho hills that covers approximately 3,532km^2 and 2,170km^2, respectively. The springs in these hills are located at an altitude ranging from 650m to 1,160m above sea level. The hills functions like water reservoirs for the springs that sprout on the slopes of the two hills. This chapter provides background information and justification of the study which includes goals and objectives of the study.

1.2 Background Information

Spring are important components of the hydrosphere (Lvovitch, 1977). In semi-arid regions of Kitui County, springs are found on the forested slopes of high mountains and hills such as those in Nuu region. These springs emanates from unconfined aquifers and are considered important sources of water for rural communities in the Nuu region. Due to the impacts of climate change particularly changes in rainfall amount and intensity, reduction in the spatial- temporal distribution of rainfall and a marked decline in the total annual rainfall, coupled with other anthropogenic causes, the springs in Nuu Hills are drying at a rapid rate (Tambe, et al., 2012). This is leading to reduction of base-flow in seasonal rivers emanating from Nuu Hills. This in turn has reduced the availability of water for both domestic and livestock uses.

Null and Mutaitho hills in Kitui County lies in the south eastern part of Kenya. The region has a reputation for its relatively high temperatures and low rainfall amounts in any given year. The average rainfall received in the county ranges from 250 to 850mm/year with a very low reliability in some areas (Berry, 2003). The study area is generally characterized by hot and dry climate with unreliable rainfall and erratic seasonal stream flows. The region is predominantly arid and semi-arid with the maximum mean annual temperature ranging between 26^{o}C and 34^{o}C are high throughout the year and the mean annual potential evaporation rates range from 2000 to 2200mm (Berry, 2003). The region has two rainy seasons falling in the months of April-May (long rains) and November-December (short rains). The two rainy seasons are unreliable and therefore surface water sources are scarce.

People in the Nuu region are heavily dependent on springs and seasonal rivers for water supply. Although there are also found several earth-dams, water pans and boreholes, these water sources do not last more than 6 months during dry period. Therefore, water shortages for domestic use and small scale irrigation farming in Nuu ward is a serious problem especially during the long dry spells which run from May to November. As a result, most of the local community depends entirely on relief food and domestic water supply from seasonal rivers, which dry out very fast following cessation of rainfall. During the dry period, local community tends to converge at the Nuu springs to scramble for the little remaining flow from the springs.

The Nuu and Mutaitho hills catchment area cover a surface area of approximately 3,532km^2 and 2,170km^2 respectively and are the source of 13 springs. However, three of the springs are either dry or are showing signs of decreasing flows while the rest of the springs are still high yielding. The springs that are still yielding water include Kavui, Makaveti, Mola, Wikya, Nuu, Kiviu, Kiwani, Kasyungala, Minyiini and Kaunzuu. The springs with declining flows are Kanyululuni, Kyatuka and Mutaitho. The springs lie within an altitude ranging from 650m to 1,160m above sea level and within latitudes 37m 429000/37m 420000 and SS9888000/9875000 Universal Transverse Mercator (UTM).

The Nuu springs have been sources of water for the people of Nuu area for a long time. In the early days, the hill was also a settlement area. In the 1950s, the colonial government gazetted part of the hill in order to protect the springs which were drying up due to the human settlement within the catchment (Imbernon, 1999). However, after independence in 1963, the local community started encroaching on the hills and by the year 2000, a high percentage of the catchment had already been settled (County MWI, 2016). The increased settlements on the hills led to increased rate of deforestation, soil erosion, and gully formation. This subsequently interfered with the recharge of springs due to degradation of the recharge areas and this is thought to have led to progressive drying-up of the springs. Before the year 1980, the hilltops were not highly inhabited, and therefore the forest cover provided the ideal conditions for proper recharge of the ground water aquifers in the area and the continuous high yield from the Nuu springs.

Previous studies have shown that Kitui County in general had many springs, which were flowing from the existing semi-arid hills (Gachari, et al, 2011). This was due to the fact that most of the sources of springs were intact with very low rate of encroachment. Currently the springs are diminishing rapidly due to degradation of the catchment areas (County MWI, 2016). Despite incremental improvements in our ability to quantify rates of forest clearing, there is still no definitive understanding of the extent of degradation of Nuu hills forests which are sources of springs found within the region. There is need for research on the causes of degradation of springs, without those studies forest conservation policy responses will be poorly reformed and ineffective in addressing the root cause of forest cover change in Nuu region (Pellikka et al., 2009). Due to the increasing demand of water as a result of climate change and the necessity of environmental protection, there is increasing need for the protection the Nuu hills. In the year 2006, the Forestry Department formed a contingent team based at Karura forest which evicted people from the gazetted forests (Imbernon, 1999). Thus by the year 2010 all the people living above the forest cut lines had been evicted from the Nuu hills (County report, 2015). However, despite these efforts, forest degradation on the Nuu Hills has continued to occur with serious impacts on the springs.

1.3 Statement of the problem

Kenya is classified as a water scarce country and this implies that it is below the global cut-off point of $1000m^3$ per capita water availability (Mulinge, et al., 2015). The country currently has a per capita water availability of about 637 m^3 (Mulinge, et al., 2015).The scarce water resources need to be protected in order to provide water for both domestic, livestock and commercial uses (Mulinge, et al., 2015). The Kitui region is categorized as being an arid and semi-arid area, with relatively high water scarcity. Water shortages for small scale-farming and domestic use in Nuu ward is serious problem especially during the long dry spells in the period between the months of May and November. Although rainfall is experienced in Nuu region, it is in intermittent short high intensity storms which are highly unreliable hence limiting the capability of the local communities to harvest direct surface runoff for use during the dry period (Belkhodja, et al., 2003). This makes the local people to depend almost entirely on relief food and domestic water supply from erratic stream flows which usually dry up shortly after the rains have ceased. During this period the local communities tends to converge at the spring sources to scramble for the little remaining flow from the springs. The springs at Kiwani, Nuu, and Mola are already overstretched such that huge crowds of people, together with their livestock are normally seen flocking the few remaining spring water points (Plate 1).

Figure 1-1: Kiwani spring water kiosk with community queuing for water.

The Nuu and Mutaitho hills springs act like a life-saving oasis in this arid and semi-arid lands (ASAL) region of Kitui County. Thus, any attempt to protect or revive the springs will considerably ease the water shortage. In addition, schools, hotels and dispensaries lack enough water during the dry period and thus the hygiene and sanitation levels are hence compromised. It is important to note that availability and quality of water in many regions of the world is associated with the existence of the forests (Pellikka, 2009). However, the quality of clean water is increasingly threatened by human induced changes such degradation of forested catchment areas. In this regard, the interaction of forests and water resources is the most critical issue that must be accorded the highest priority in research because of its unique characteristics and impacts on availability of both streams and springs (Laws, 1970). With the projected global increase in human population, demand for fuel and other forest products is estimated to increase greatly and therefore drastically affect the water availability in different parts of the world

(UNEP, 2006). Over the past decades, terrestrial water flows have been affected by humans at an unprecedented scale and the rate of forest cover degradation is reported to be on the rise (UNEP, 2006).

In Kenya, land tenure systems are classified in three broad categories: (i) Trust/Communal Land which is held by local authorities on behalf of the local communities; (ii) Public land, held by the central administration on behalf of the public and (iii) individual/private land owned in either freehold or leasehold (Kostrowicki, 1983). Most of the land in the study area is communally owned as trust land under county government, even though this is undergoing change and more and more communal owned land is changing into individual or freehold ownership (Maguma, 2014). This trend had a large influence on the agro-pastoral lifestyle since private ownership restricts movement under the traditional land-use management systems. This change contributes to more deforestation within the scattered settlement in the Nuu Hills catchment area and more land is put under cultivation thus putting springs at risk. Land clearing in the study area is assumed to be the key cause of the decrease in spring discharge. The increasing aridity in the area is thought to be associated with climate change and forest degradation as land is highly degraded as a result of the human activities within the area (Wohl, 2006), both surface and ground water sources are rendered susceptible to depletion due to increased evaporation rates which are as a result of direct solar radiation on the former forest ground surface.

The settlement on the Nuu hilltops have also caused serious disturbance on the land cover and hence are thought to have been caused by hydrological imbalances which are evidenced by the drying up of a number of streams and springs emanating from these hills. The condition has further been worsened by the issue of effects of climate change on water resources and variability in rainfall patterns in the region (Chiwa, 2012). This has led to the increased frequency of hydrological droughts in the area resulting in increased water scarcity and water conflicts in the area. This has also threatened the ecosystems in the area and the people that depend on water from the hills for their day to day water needs. Therefore this study attempts to examine the extent to which the degradation of Nuu hills catchment area has impacted on the springs emanating from the hills.

1.4 Goals and Objectives of the Study

1.4.1 Goal of the study

The goal of the study is to determine the main causes of decline in spring discharges in Nuu and Mutaitho Hills catchment areas in Kitui County.

1.4.2 Specific Objectives

The specific objectives of the study are as follows:

i. Assessment of the relationship between spring discharges and the rate of deforestation in Nuu and Mutaitho hills catchment area in Kitui County.
ii. Establish the relationship between spring discharges and rainfall variability in the Nuu and Mutaitho hills catchment area in Kitui County.
iii. Determine the socio-economic and environmental impacts of decreasing spring discharges in Nuu region of Kitui County.
iv. Provide policy recommendation for sustainable management of springs in the semi-arid like Nuu and Mutaitho hills catchment area in Kitui County

1.5 Research Hypotheses.

The study has two (2) main hypothesis that are formulated as follows:

1.5.1 Ho: There is no significant relationship between spring discharges and the rate of deforestation in Nuu hills catchment area in Kitui County.

H_1: Alternative.

1.5.2 Ho: There is no significant relationship between spring discharges and rainfall variability in the Nuu hills catchment area in Kitui County.

H_1: Alternative.

1.5.3 Ho: There is no significant relationship between spring discharges and social-economic and environmental impacts in the Nuu hills catchment area in Kitui County.

H_1: Alternative.

1.6 Justification of the study

Kenya is classified as water scarce country with per capita water availability of about 637 m^3 (USAID, 2000). Kitui County found in arid and semi-arid region is also a water scarce region. The scarce water resources that are currently available need to be protected in order to maintain water security and provide water for domestic and commercial needs (USAID, 2000). In the study area, it is suspected that the decreasing spring discharges is due to deforestation, rainfall variability and increased human settlement on the hills due to rapid population growth within the catchment area. Thus, this study aims at establishing the main factors that are causing the declines. This will contribute in addressing issues of catchment degradation in the arid and semi-arid area in Kitui County.

Land is one of the main resources upon which the exploitation of other natural resources is based hence land use planning plays a significant role in altering the dynamics and the use of land based resources. Water is one of the vital resource which has impacts on livelihoods and ecosystems in the study area. Land use planning development process is therefore, likely to promote strong reactions from diverse conflicting interests by assessing internal and external factors influencing land use.

Nuu region being an arid and semi-arid region which is characterized by low rainfall leading to shortage of water for domestic use, increased poverty due to lack of water for food production and agribusiness. It is therefore important to establish how springs water production is related to the forest deforestation, studies of this nature provides data and information that can be used by the stakeholders in decision making, particularly planning for sustainable catchment management. The results attained from this study will have important implication on the assessment of the net benefits of deforestation mitigation strategies such as afforestation/reforestation and for understanding the changes in Nuu region.

With the projected level of growth of infrastructure in the study area, the Nuu springs will play a key role in the future development of the area. Nuu springs are of substantial value to the local communities. Water being a scarce commodity and with the current trend of land use, water resources will even be more scarce in the county. Hence there is a need to carry out more research in order to provide recommendations and strategies on how springs in the Nuu Catchment area can be sustained on long-term basis. This study will also enable the achievement of the goals of the Kenya's Vision 2030 as well as Sustainable Development Goals (SDGs). Due to the major impacts of declining spring discharges and the need for reversing the trends, this study is therefore considered to be important. The availability of quality clean water is increasingly threatened by human induced forest changes. In this regard, the relationship between forests and water resource is a critical issue that must be accorded the highest research priority. The study has combined extensively studies on the forest and springs discharge across the study area with historic data to show how rapid deforestation is affecting springs and other water resources in the arid and semi-arid regions of Kitui County.

The impacts of past, present, and future deforestation mostly caused by land use changes have been investigated in numerous studies (Brovkin, et al., 2006, House, et al., 2002, Goudie, 2013). These studies have established that the deforestation process primarily effects rainfall patterns and springs production and this has strong effects to the local communities. The research will therefore contribute in unraveling causes of vanishing water springs in most parts of arid and semi-arid areas of Kenya. For the next generation to experience a better and secure future in terms of water security, there is a need for the sustainable management of natural resources in a sustainable manner. This study, examined whether the existing springs are affected by forest cover changes which are due to rapid development evidenced by increasing rate of deforestation and decreasing rainfall variability.

1.7 Scope of the study

This study examined the effect of deforestation to springs at Nuu and Mutaitho hills in Kitui County. The study focused on the gazetted areas of the hills which were supposed to be left under natural vegetation forest cover. The study also focuses on establishing the extent of forest cover changes from 1981 to 2015 including the corresponding changes in rainfall patterns and spring discharges in the Nuu region during same period. To obtain data of what happened in this area, the study relied on the knowledge of the local communities who have settled on the hills. The study focused mainly on spring discharges in the past 30 years' (1980 to 2010).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter is focused on the review of studies that have been undertaken on the effects of deforestation on springs. This mostly entailed the review of studies undertaken in various parts of the world. This is then followed by the review of local or regional studies in Africa and East Africa, respectively. The literature review was achieved through review of papers published in scientific journals, technical reports, and research thesis.

2.2 Causes of forest degradation

Forest degradation occurs when changes within the forest negatively affect the structure and function of the forest stand, and thereby lower the capacity to supply products and/or ecosystem services. Forest degradation creates less resilient and less productive forests and in some countries, it can be harmful (Allen, et al., 1985). Forests are cleared for many reasons, but most of them are related to money or to people's need to provide for their families. The largest driver of deforestation is agriculture (Lambin, et al., 2001, Zhang, et al., 2004). Farmers clear forests to provide more room for planting crops or grazing livestock. Often many small scale farmers will each clear a few acres to feed their families by cutting down trees and burning them in a process known as "slash and burn" agriculture (Andreessen, 2004).

With the world population growing at rapid growth rate, the increasing need for space is turning out to be an area of concern. With desperate need for land for agricultural, industrial and most importantly urban needs for expansion of cities and their growing population, a direct action that we have come to recognize as "Deforestation" occurs (Pellikka, 2009). Deforestation in simple term means the felling and clearing of forest cover or tree plantations in order to accommodate agricultural, industrial or urban use (Pellikka, 2009). It involves permanent end of forest cover to make that land available for residential, commercial or industrial purpose (Pellikka, 2009).

Over the last century the forest cover around the globe has been greatly compromised, leaving the green cover down to an all-time low of about 30 per cent. According to the United Nations Food and Agriculture Organization (FAO), an estimated 18 million acres (7.3 million hectares) of forest are lost each year (FAO, 2010). Deforestation can also be seen as removal of forests leading to several imbalances ecologically and environmentally. What makes deforestation alarming are the immediate and long term effects it is bound to inflict on the affected areas. Some predictions state that the rainforests of the world will be destroyed completely if deforestation continues at the current pace (FAO, 2000).

As earlier mentioned, agricultural activities are some of the major factors affecting deforestation. Due to rapidly growing demand for food products, huge number of trees are felled down to grow crops and open more land for cattle grazing. Apart from this, wood based industries like paper, match-sticks, furniture etc., also need a substantial amount of wood supply (Imbernon, 1999). Wood is also used as fuel both directly and indirectly, therefore trees are chopped for supplies. Some of these industries thrive on illegal wood cutting and felling of trees. Further in order to gain access to these forests, construction of roads are undertaken; here again trees are chopped to create roads. Overpopulation is directly affecting forest covers as more areas for settlement are cleared. Expansion of cities is also affecting the forest cover as land is required to establish housing and settlements and therefore forest land cleared (Imbernon, 1999). Some of other factors that lead to deforestation are anthropogenic in nature. Many industries release their wastes into rivers which results in soil erosion and make it unsuitable for growing plants and trees (Schulze, et al., 2012).

2.3 Effects of Deforestation on springs discharge

Deforestation has many negative effects on the environment (Porter-Bolland et al., 2012). The most dramatic impact is loss of habitat for numerous species. Seventy percent of earth's land animals and plants live in forests, and many cannot survive the deforestation that destroys their habitats (Porter-Bolland, et al., 2012). Deforestation also affects the climate in more than one ways. Trees release water vapor in the air, which is compromised with the lack of trees. Trees also provide the required shade that keeps the soil moist. This leads to the imbalance in the atmospheric temperature further making conditions for the ecology difficult (Schulze, et al., 2012.) These haphazard clearances of forests have forced several of these animals to shift from their native environment (Wilson, 2002). Due to this several species are finding it difficult to survive or adapt to new habitat.

Forest play a major role in controlling ground water table by providing shade to reduce evaporation for the soil to remain moist and also utilize the greenhouse gases in order to restore the balance in the atmosphere. With constant deforestation, the ratio of greenhouse gases in the atmosphere has increased, adding to global warming (Gaertner, et al., 2001). With the clearance of tree cover, the soil is directly exposed to the sun, making it dry. When it rains, trees absorb and store large amount of water through their roots (Breda, et al., 2006) When trees are cut down, the flow of water is disrupted and this leads to floods in some areas and droughts in others. Due to massive felling down of trees, various species of animals are lost, they loose their habitat and are forced to move to new locations. Some of them are even pushed to extinction. The world has lost many species of plants and animals in last couple of decades (Gaertner, et al., 2001).

An estimated 13 million hectares of forests were lost each year between 2000 and 2010 due to deforestation (Małek, et al., 2014). In tropical rainforests particularly, deforestation continues to be an urgent environmental issue that jeopardizes people's livelihoods, threatens species, and intensifies global warming. Forests make a vital contribution to humanity, but their full potential will only be realized if deforestation and forest degradation can be stopped. Deforestation and forest degradation can cause wildlife to decline. When forest cover is removed, wildlife is deprived of habitat and becomes more vulnerable to hunting. Considering that about 80% of the world's documented species are found in tropical rainforests, deforestation poses a serious threat to the earth's biodiversity (Malcolm, 2006). As a result of deforestation, trees no longer evaporate groundwater, which can cause the local climate to be much drier. Deforestation also accelerates rates of soil erosion, by increasing runoff and reducing the protection of the soil from tree litter. Millions of people rely directly on forests, through shifting cultivation, hunting and gathering, and by harvesting forest products such as rubber. Deforestation continues to create severe social problems, sometimes leading to violent conflict (Andréassian, 2004).

Along with the fast population growth and the development of developing countries, there is a high demand for fuel wood, charcoal and timber production by dwellers and other institutions. It is also used for construction of farm implements, fences, furniture and houses, serve as a source of pasture for their livestock, and provide other environmental and social services to the community (Duckworth, et al., 1993).

A more workable solution is to carefully manage forest resources by eliminating clear-cutting to make sure that forest environments remain intact. The tree felling that does occur should be balanced by planting of enough young trees to replace the older ones felled in any given forest. A number of new tree plantations which is growing each year is equals to a tiny fraction of the Earth's forest percentage required. According to a U.S Geological Survey (2011), there is adequate water in the globe to meet the needs of the earth's population (Malcolm, 2006). The Report further points out that if the global fresh water resources were well utilized the problem of access to water would be a thing of the past. This position is affirmed by a UNESCO (2006) study which blames the current global water crisis not, on lack of water supply or technology, but rather on the failure in the governance of water. That is, today's water crisis are not caused by the fact of having too little water to satisfy people's needs but rather it is a crisis of managing the water so badly that billions of people do not access the water.

2.4 Variability of rainfall on springs

Improving access to water has been the interest of most governments and many other different organizations. Water supply and sanitation coverage for African countries remains the lowest at 62% and 60%, respectively (WHO/UNICEF, 2000).The term land in Kenya can have several connotations; for government land is the physical space which represents the cultural, political and social power of the Nation; for people land means a source of livelihood and it determines the level of prosperity or poverty (KLA, 2000). The change in land use from forest to agricultural land started in 1970 when the government tried to create space for crop production and settlement for people which has increased in the last decade considerably. Study done by Lambin in 1997 showed that, 64 per cent of Kenya's land area was potentially subject to moderate desertification and about 23 per cent were vulnerable to severe to very severe desertification, 52 per cent to moderate land degradation, and 33 per cent faced slight vulnerability to degradation (Lambin, 1997). Most studies done recently by World Health Organization (WHO/UNICEF, 2000) identified degradation in ASALs as a potential precursor to widespread desertification. In the early 2000s, approximately 30 per cent of Kenya was affected by very severe land degradation and an estimated 12 million people, or a third of the Kenya's population, depended directly on land that is being degraded (KLA, 2000). The droughts of 1970-2000 accelerated soil degradation and reduced per-capita food production (KLA, 2000).

Water sector targets in the vast Eastern Province are to ensure that every person have a safe and secure access to water for their domestic purposes which is in line with the Kitui county mission of improving the livelihoods of all citizens (Gachari, et al., 2011). Forest degradation will make it difficult to achieve these targets. Unfortunately, it has been estimated that about half of the earth's mature natural forests have now been destroyed (UNESCO, 2005). It has been predicted that unless significant measures such as protecting forests that has not been disturbed are taken on a worldwide basis, by 2030 only 4% of the forest cover will be remaining (Nelson, et al., 2006; Wilson, et al., 2002). A 2002 analysis of satellite imageries suggested that the rate of deforestation in the humid tropics was roughly 23% lower than the most commonly quoted rates (Achard, et al., 2002).Where infrastructure for water supply has not been fully developed, rivers provide a direct source of water for domestic use with minimal or no treatment at all. For water scarce countries, including Kenya (WRI, 2007), this means that water catchment areas should be managed properly so as to retain their capacity to supply good quality water all year round. Thus, understanding the possible consequences of land use and land cover changes on water resources is a requisite for better water resources management.

2.5 Studies done at regional levels

Drivers of deforestation, conversion and intensification are driven by a variety of factors at both global and regional levels. Every year, world population grows by 80 million people (UN, 2008), while the average standard of living increases (World Bank, 2010). The combined effect of these trends is increasing demand for natural resources and settlement Land.

Africa boasts over 4 million first-order streams that were originally in forested catchments. However, loss of indigenous forests and their subsequent conversion to agricultural use in East Africa, for example, is one of the major threats to surface water quality (FAO, 2010).Recent studies showed that the population size has greatly increased and at present the rapid population growth has more effects on forest. This dramatic increase of population coupled with the higher demand of fuel wood and construction materials create huge pressure on the forests which also affects the water towers (World Bank, 2010).Achard and other researcher's in 2002 conducted a study to determine the impact of human activities on the forest and associated natural resources within the NechSar National Park. Data was collected by tallying people who were entering and coming out from the park carrying different products they have collected from the forest. The result showed that, impact of the product collection was confirmed from the views of the occupants of the surrounding community through interview. The study showed that the flow of springs and ground water level was affected.

Relationship between land use and hydrology has been investigated extensively in Tanzania by Chiwa, (2012) who also conducted another study on effects of land use and land cover changes on hydrology of Weruweru-Kiladede Sub-Catchment in Pagani river basin in Tanzania. Satellite data was integrated in GIS to examine the extent of land-use and cover change in the sub-catchment. The results showed that "Land-use and land-cover changes have negative consequences on watershed management. They increase impervious ground surfaces, decrease infiltration rate and increase runoff rate, hence causing low base flow during the dry seasons" (Chiwa, 2012).

There are potential impacts on physical and social dimensions throughout the entire history of mankind. Intensive human utilization of land resources has resulted in significant changes on forest cover. Since the era of industrialization and rapid population growth, land-use change phenomena have strongly accelerated in many regions. Land-use changes are frequently indicated to be one of the main human-induced factors influencing hydrological systems. 8000 years ago, it was estimated that undisturbed forest areas represented 50% of the earth's land surface (Mittermeier, et al., 2003), as opposed to 10% today Agriculture has expanded into forests as the population growth is rapidly shooting up and the option is only the fertility of the forested area aiming at high production which is at par with the food security level (Andréassian, 2004).

2.6 Studies done at Local levels

Study conducted by Masese, (2009) on effects of deforestation on water resources in Sondu Miriu River basin in Kenya showed that deforestation has been reducing magnitude and frequency of runoff events and reduced base flows, increased pesticide contamination, erosion and sedimentation of streams and rivers and the same will be in catchment areas of the streams and rivers which starts as springs in the water towers. (Masese, et al., 2009; Małek, 2014).

Study done by RURI Consultants (2013) analyzing causes of forest cover change in the various forest types of Kenya based their study on Mau forest which is the major towers in Kenya showed that; the Mau Forest Complex has witnessed considerable land use and land cover changes over the years with the closed canopy forest cover currently standing at a paltry 2.0% (The World Bank, 2007). Most of these forests are mountain forests and they constitute the nation's water towers.

Study done by Masese on effects of deforestation on water resources in Sondu-Miriu river brings up the facts that there is an enormous impact on water towers which is coming up due to forest degradation. Masese have recommended an immediate land reclamation as mitigation factor to save our water towers in Kenya. The same has also done by Mati, Mutie, Gadain and Mtalo in their study on Impacts of land use or land cover changes on the trans-boundary Mara River in Kenya and Tanzania in the existing lakes and reservoirs of the same region. They also found that there is a relationship between the land cover changes and the reduction in water tables and water levels in the lakes and water reservoirs.

2.7 Research Gaps

After literature review, the following are the viewed as the main research gaps which this research will address. In Scientific and technical knowledge, education is generally highly sectoral. Community education across disciplines is necessary to improve knowledge of forest and water interactions, e.g. to improve capacity to assess the effects of afforestation and reforestation programmes on water quality and quantity, flood control and soil protection. Despite the significant advances in scientific understanding of forest and water interactions, the role of forests in relation to the sustainable management of water resources remains is contentious issue because of difficulties in transferring the understanding to the local communities. Another difficulty, is the gap between research and policy, which persists at least in part because of a general failure to communicate results of hydrological research effectively to policy-makers and to challenge conventional assumptions with scientific evidence. This has been evidenced by the existing policies that takes long to change, despite lots of research findings that are documented to address the same.

Impacts of forest change on overall anthropogenic activities are likely to trigger economic vulnerability at the local level and little is known about such vulnerability. The impacts of forests change on rainfall reliability and springs production within Nuu region will depend on the future effects of agriculture, settlement, economic activities and infrastructure development. While most studies available have focused on the rapidly declining the role of community in the overall ecosystem functions, there is no consistent and comprehensive studies linking the forest, water and anthropogenic activities have been undertaken in Kitui County. More research is required to identify highly vulnerable micro-environments and associated communities to provide agronomic and economic coping strategies for the affected populations.

Ecologists are well aware of the risks when land is managed without a sound scientific understanding of the structure and functioning of ecosystems (Slocombe, 1993). However, there is still a large gap in our understanding of the relationship between forests and springs, thus impairing our capability of implementing forest conservation strategy. Hence, a study on how human intervention mediates the adaptation of forests to anthropogenic activities and prevents ecosystem degradation needs to be undertaken. This study aims at promoting consensus on the key issues concerning forest and water interactions, and to identify areas of uncertainty on which to focus policy-relevant research.

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA

3.1 Introduction

This chapter provides background information on the study area. The chapter provides details on the climatic conditions, hydrology and drainage, vegetation cover and land use, population and social economic activities in the study area. The chapter was prepared through collection of exiting data and information from technical reports, research theses and published scientific journals papers, among others.

3.2 Location

The Nuu Hills are found in Mwingi Sub-county, in Kitui County in Eastern Kenya. The area is located about 200km east of Nairobi (Figure 3-1). The Nuu Hills region covers an estimated surface area 196km^2. (Avanloon, 2009).

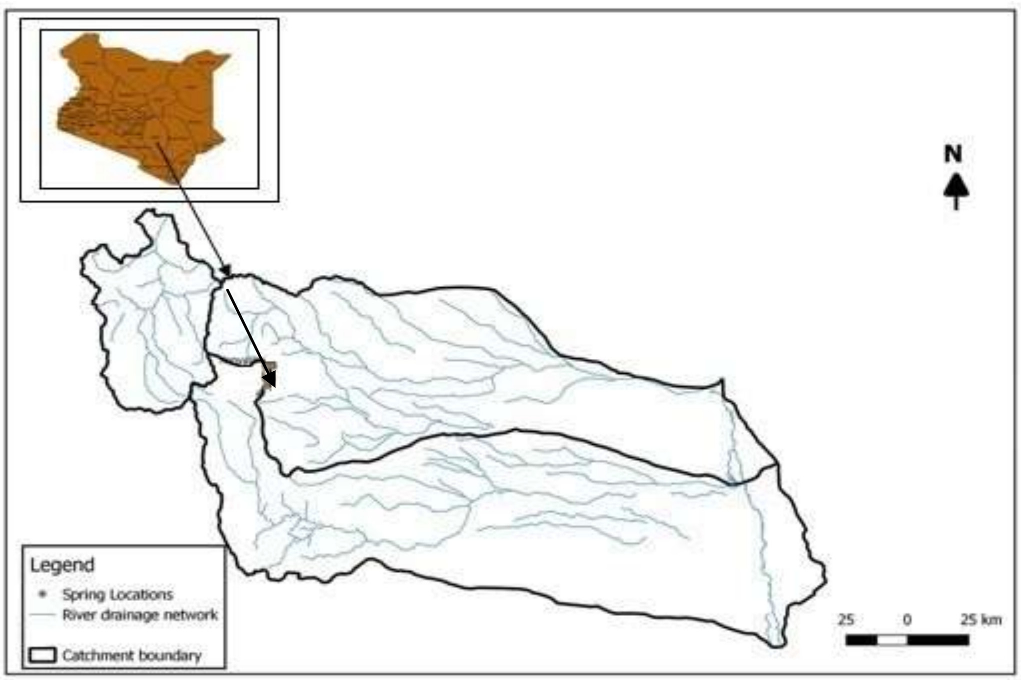

Figure 3-1: The location of the study area (Nuu and Mutaitho hills) within Kitui County in Eastern Kenya *(Source www.csiagr.org).*

Figure 3-1 shows the location of Nuu catchment area in Kitui County. The study area is limited within the two hills namely Nuu and Mutaitho hills. There are three highest areas within the study area; the upper highest section is located within the boundaries of Mui and Mutyangome locations which is not part of study area. However the second and third highest sections of the areas are the two hills namely Nuu and Mutaitho hills, respectively (Figure 3-2). Nuu hill which is in the center of the study area covers sections of two Locations namely Mutyangome and Nuu locations, Mutaitho hill is within Nuu location. Figure 3-2 provides details of the location of springs and general drainage within study area.

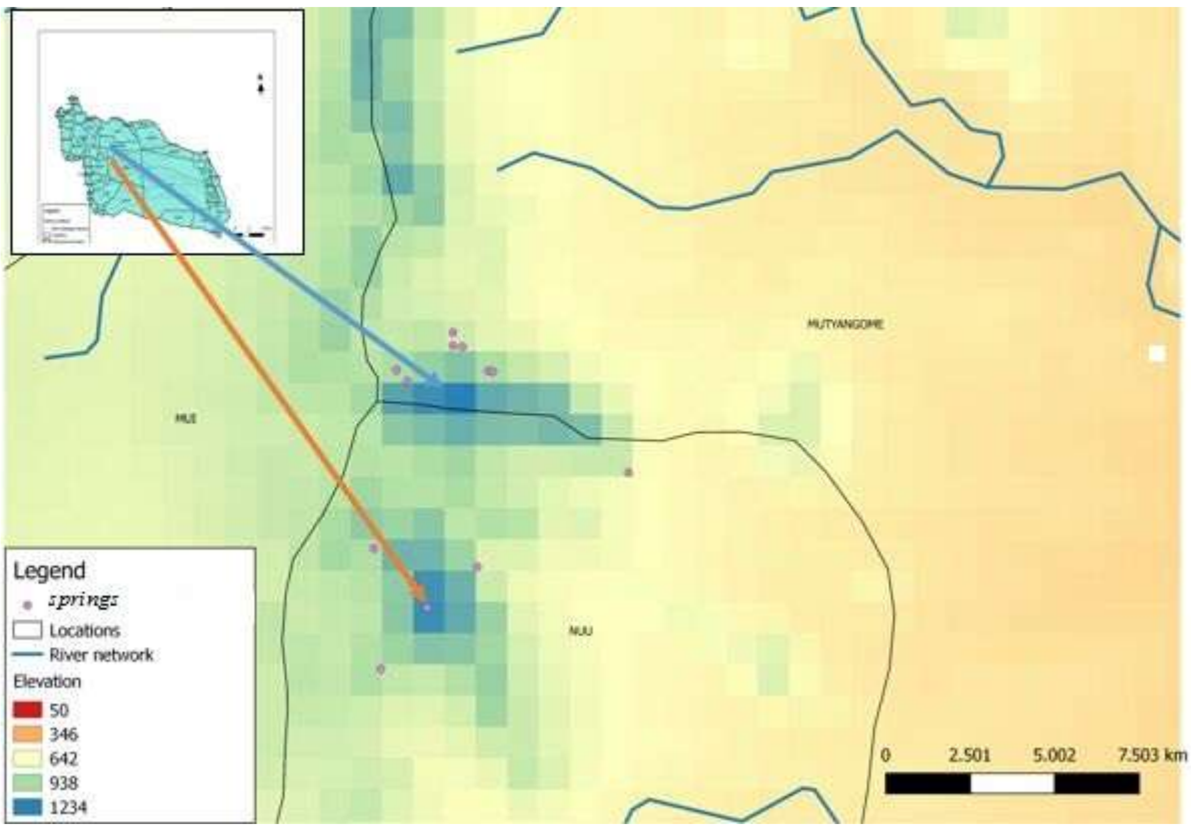

Figure 3-2: The location of springs within the study area (Source www.csiagr.org)

3.3 Climatic conditions

The climate of the study area is generally semi-arid with erratic bimodal rainfall occurring in the period between October and December during short rains and in the period between March and May during long rains. The total annual rainfall ranges from 250 to 750 mm/annum. The temperature is relatively low with an annual mean of about 21.5^{0}C (Mutembei et al, 2015). The area is characterized by high runoff generation and is highly eroded and this is due to the fact that during the dry season the rainfall that falls on the hills is very erosive due to low level of vegetation cover in the area and the steep slopes in the area (Mutembei, et al., 2015).

3.4 Hydrology and drainage

The drainage of the study area includes streams which lie within the Tana River basin drainage. The streams flow from North-West to South-East direction. Generally, the drainage system flows from the recharge area (hilly areas) and discharges in to the small and major streams.

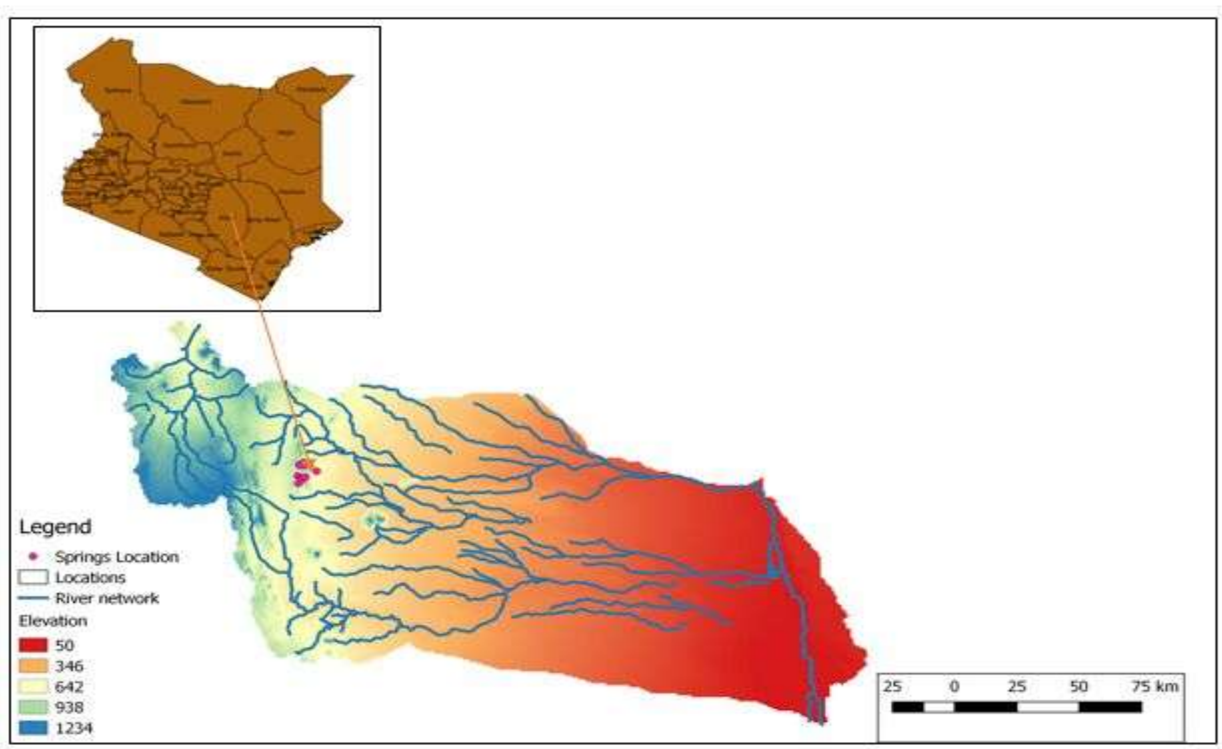

Figure 3-3: The drainage network and elevation of the Nuu region (Source www.csiagr.org)

The study area has several streams which are classified as either seasonal or ephemeral streams with the implication that flow in them occurs only during the rainy season and shortly after the rain storms has passed (Borst, et al., 2006). The Nuu Hills springs are found within the Tana river catchment area. The hydrology is influenced by flow of seasonal streams in the upper reaches of the catchment. There are noticeable small tributaries which drain the Nuu/Mutaitho hills catchment (Figure 3-3). Physiologically, the hydrology is influenced by hills, where most streams originates. Due to the stream network combined with effective drainage and the increased frequency of extreme hydrologic events, there has been increased soil erosion in the basin. Unfortunately, there are no data on the flow trends of streams in this area due to lack of hydrological monitoring in the area and the erratic and seasonal nature of the streams. Most of the streams flowing from Nuu and Mutaitho hills are tributaries of Enziu river which drains to Tana river.

3.5 Vegetation

The vegetation of the study site is highly heterogeneous probably due to variation in both soil type and history of land use (Belkhodja, et al., 2003; Omondi 2007). Large areas of the study site are occupied by bush lands, grasslands and shrub-lands, comprising various combinations of dry land vegetation as shown in Figure 3-4. The study area is characterized by semi-arid vegetation. However, the area has a rich diversity of plants and animal species most of the tree and shrub species are concentrated on hilltops especially Mumoni and Nuu hills. Along the river beds some of the indigenous species such as *Ficus spp*, and *Melia volkensiare* have been wiped-out (Mulwa, 2015). The existing trees around the springs comprise of acacia species, *balanities anetica* species, *Terminalia indica*, *Ficus syconium* and *comifolus* species. Those that fall on private lands are threatened due to harvesting for timber and charcoal production (O'Leary, 1980; Kigomo, 1991). Hill top cultivation is also a threat to conservation of biological biodiversity. According to the Mwingi Environmental Action Plan, over half of Mwingi is occupied by pastures and woodlands that are not distinguishable from each other. About one third is dedicated to agriculture. Forests and Hills in the study area are gazetted, or set aside for forestry (while some hills are plain rock outcrops) (Shelmith, et al; 2014; Kigomo, 1991). The upper reaches of the rivers depicts homogenous mix of plant species adapted to moderate conditions and low to moderate rainfall. About 80% of the area has a rich accumulation of live and dead biomass. Human activities have significantly eliminated natural vegetation for cultivation, timber production, wood fuel, charcoal burning and settlement. However, indigenous plants are still notably in most areas. In other parts, a local community has adopted planting of exotic plants.

3.6 Geology and Soils

The soils of Nuu region reflect the largely metamorphic parent rock material and the rainfall regimes that contribute to their formation. A rough estimate of the agricultural quality of the soils indicates that less than 20 per cent of the area has well-drained, deep, friable red and brown clays of good fertility; more than 60 per cent of the region has very erodible, relatively shallow, sticky, red, black, and brown clays of variable fertility, on steep slopes; 20 per cent has poorly drained, shallow, Stony soils of low fertility (Rocheleau, et al., 1988). Black cotton soils occur in the western part of the county, but elsewhere distinctive red sandy soils of low fertility are present. The geology of the study area is characterized by the basement complex of metamorphic and igneous rocks, whose weathered mantle is of varying thickness (Abuga, 2014). The southern side of the county is underlain by Permian deposits. The overall groundwater resources are scarce and rivers only flow during the wet seasons (Abuga, 2014).

3.7 Land use

Most of the land in the study area is not demarcated hence owners of land do not have title deeds. Land is mostly owned by households. The farm sizes ranges from 60 acres to about 6 acres of land per household (Aremde, et al., 2012). Within the study area communities use land for domestic or subsistence farming due to the climatic conditions of the county (Aremde, et al., 2012).

The study area is utilized by pastoral and agro-pastoral communities (Figure 3-4). Due to the nature of the rainfall patterns within Nuu region, production is more reliable for households growing resilient crops such as millet, sorghum, green grams and cowpeas, but the pressure to sell these food crops in order to generate household income needs is great and leaves many households vulnerable, thus al communities resort to other income generating activities such as charcoal burning and selling, tree logging and bee keeping for honey. Coal deposits are said to be present but mining has not yet started (Syengo, 2015).

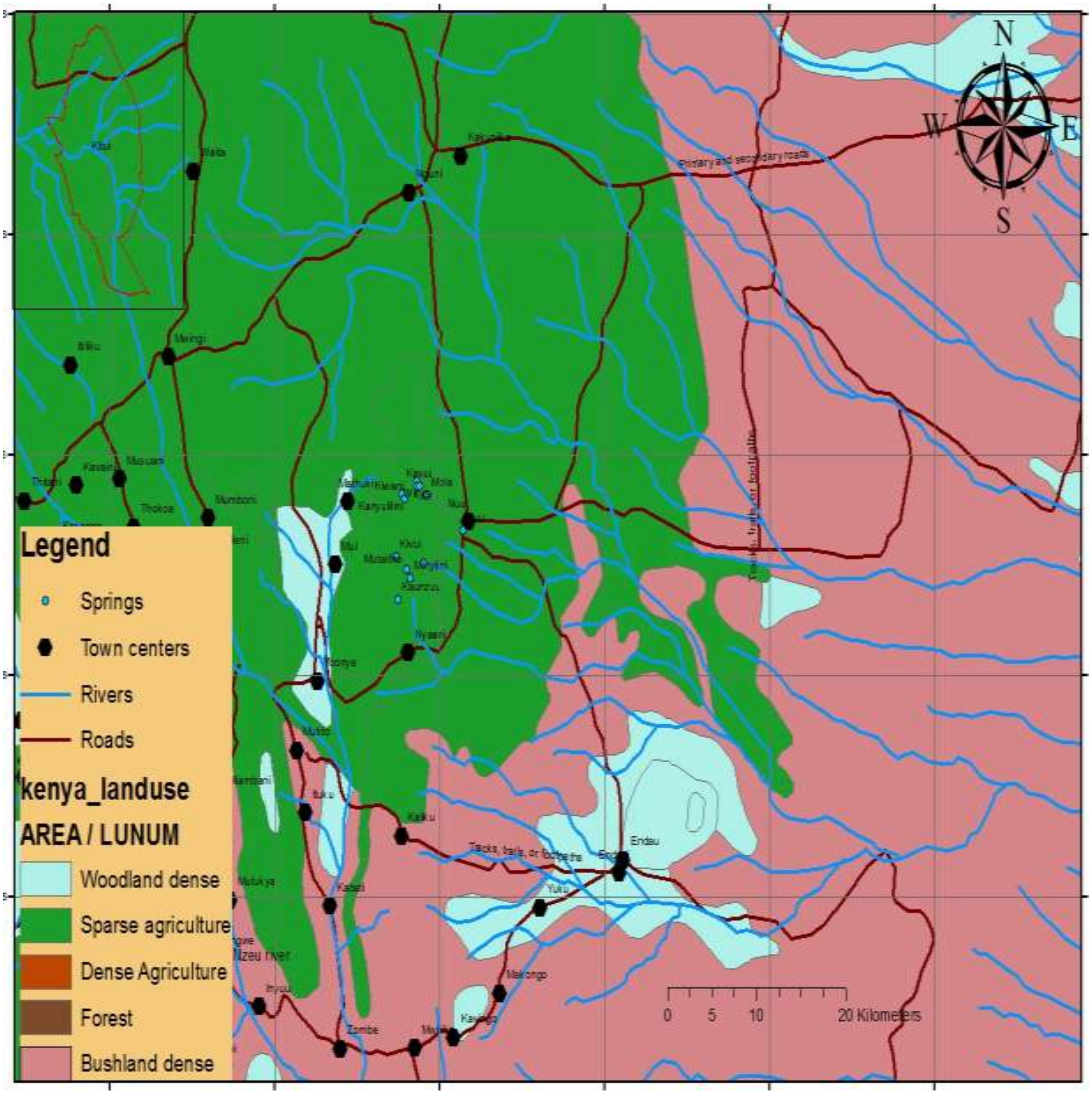

Figure 3-4: *Land use pattern in the Nuu region*

3.8 Population

Kitui County has a population of 1,012,709 while Nuu location where the two hills are located has a total population of 24,850 persons according to Kenya National Bureau of Statistics (2009). With the current population growth rate of 2.1 % annually, the population of Nuu region is projected to be 28,502 by end of 2016 (Aremde, et al., 2012; WRI, 2007). The population pattern in the study area is largely affected by the land ownership and land holding and also majorly by the fertility of the soils and the accessibility to water sources. Water resource is one of the limiting factors in the distribution of population in the study area. The population density ranges from 25 persons per km^2 to 44 persons per Km^2 (National Bureau of statistics 2007).

3.9 Socio-economic activities

The study area falls within agro-climatic zones V and VI. Climate is generally hot throughout the year with mean annual temperatures ranging from 24^oC and 30^oC (Sombroek, et al., 1982). Rainfall distribution is bimodal, with rainfall peaks in April and November. Average annual rainfall is less than 350 mm (Sombroek, et al., 1982). Under these conditions, rain-fed agriculture is unsustainable (Jaetzold et al. 2006).

The economic activities revolved around farming and agro-pastoralist placing inordinate demands on the environment for crop production and animal rearing. Livestock production is also a principal economic activity in the area, as crop production is limited to isolated pockets of cultivable land. According to Opiyo, et al., (2011), the study area is utilized by the pastoral and agro-pastoral communities, owing to the similarities of pastoral production systems in terms of culture, socio-economic and environmental characteristics. The ASALs productive capacities continued to dwindle due to inappropriate land use practices that have resulted to land degradation. The area also suffers from insecurity, poor infrastructure and limited economic opportunities. The impacts of climate change together with other challenges have caused persistent food deficits and food-aid (Odhengo, et al., 2012; GoK, 2008).The diversity of economic activities in an area shows the potential for income stream amplification and synergies relieving exploitation pressures on land and other natural resources like the upcoming coal mining might take time before its ready for exploitation. Charcoal burning and trade has been active all through but the business is not well legalized. The low levels of wage-based employment in the study area diminish the capacity to mobilize alternative financial resources thus increasing dependence on the land and natural resources (Mwema, et al., 2013). This renders the communities, especially the poor, highly vulnerable to multiple adverse effects such as droughts.

CHAPTER FOUR

STUDY METHODOLOGY

4.1 Introduction

This study involved collection of both secondary and primary data. The primary data was collected by use of questionnaires, informant interviews, field measurements and observations. The secondary and primary data included rainfall, land uses, population, spring discharges and LANDSAT data. Data analysis was done through the use of Statistical Package for the Social sciences (SPSS), Geographical information Systems (GIS) and Microsoft Excel. This chapter provides details on the methodology that was applied in the study.

4.2 Research design

In this research work, the data was gathered using both questionnaires and field data collection methods. The secondary data sources include technical reports. The primary data was obtained through personal interviews and field observations. The study area where the springs are located covers an area of 3,532 km^2which is relatively large and therefore, caution was taken in administering the questionnaires so that they do not go beyond the boundaries of the study. A simple random technique was used in administering the questionnaires to respondents found in the different parts of the study area.

4.3 Field survey

Field survey was done in order to familiarize with the study area and the local conditions in. This also allowed the researcher to have a general understanding of the study area and also to find out the key hydrologic parameters in the area prior to the proposed research works. The survey also enabled the author to have a view of the economic and land use activities in the study areas.

4.4 Methods of data collection

The primary data included data on spring discharges. These involved collection of data on the discharge from springs by measurement of the discharge using 20 liters jerican. The secondary data involved the review of technical reports and collection of data on rainfall such data was archived by the Water Resources Management Authority (WARMA) and Kenya Meteorological Department.

4.4.1 Primary data

The collection of primary data involved the application of methods listed in the following section:

4.4.1.1 Field Observations

This involved observation of various features of importance in the field. The observed features were noted in a field notebook and in some instances photographs were taken in the field. The data from field observations was used to capture the main activities that had taken place in the study area and also to be able to add and identify the knowledge gaps in the report. Satellite data was also used to determine the extent and rates of deforestation (Brown, et al., 2007; Hansen et al., 2013; Lefsky, et al., 2002). Reprocessing of data offered a number of improvements on data quality and allowed for more flexible analyses (Brown, et al., 2007). A longer time series provided more temporal context for cleared areas, and more data increase the likelihood of proper classification thus in this study it was suggested to have 20 years.

4.4.1.2 Personal interviews

In administering the questionnaires, random sampling technique was used to sample the respondents. A questionnaire was developed for institutions or organizations which exists within the study area (Annex1). This was done in order to attain data of the relationship between forests and water resources within the study area. Also, questionnaire for individual households residing in the area and who are in the proximity of the springs was developed (Annex 2). The researcher was able to capture the views of the people on the different aspects in the area of study such as deforestation extent in the catchment area as seen by the communities and impacts of springs flow variation within different seasons.

The questionnaires consisted of both closed and open ended questions. The open ended questions provided more information than close ended questions. This is because the interviewee had the freedom of giving answers other than those predetermined by ended questions. It was on this basis that the questionnaire had more of closed-ended questions than open ended ones although the structure of the questionnaires was inspired by the information that was received through the meetings held between the members of the community and the researcher. In each of the areas, the questionnaires were administered randomly. The data that was collected were translated into a format that can easily be analyzed using SPSS

4.4.2 Sampling Technique

Random sampling technique was used to come up with representative sample of respondents to be interviewed. This method provided better results when used in areas with many people. The author also opted to interview households instead of individuals so as to obtain the view of as many people as possible.

4.4.2.1 Sample Size

The sample size dictated the number of persons that were interviewed in the study area. The population sample size was determined through the use of the equation shown below (John, 2003):

$$n = \frac{z^2 pq}{d^2} \quad \text{--} \; \textbf{Equation 1}$$

Where;

n= is research minimum desired sample size

z= is standard normal deviate at required confidence level. Correspond to (1.96)

p= 20%, is the proportion of the target population estimated to be aware of the effects of deforestations.

q= is 1-p

d= margin of error (0.1)

$$n = \frac{1.96(1.96)x0.2(1-0.2)}{0.1(0.1)}$$

$$n = \frac{0.6146567}{0.01} = 61.4657 \quad \approx 62 \text{ Persons}$$

Thus, the chosen sample size was 62 persons. This was also noted to be consistent with Mugenda (1990) who noted that the sample size has to be more than 30 persons for the results to be statistically significant. The respondents of the study were identified from households and informants that are spread within the study area. The sample size obtained was proportionately allocated based on the number of households within the study area. Out of the 62 questionnaires that were administered, 10 questionnaires were administered to informants while 52 questionnaires were administered to household heads.

4.4.3 Field based measurements

The field based investigations involved the measurement of springs discharges using approaches described in section 4.4.3.2.

4.4.3.1 Rainfall Data

Rainfall data was obtained from Kenya Meteorological Department rainfall station called Nuu yard. The data was for the years 1981 to 2002 and from 2011 to 2015. The rainfall data which was used consisted of monthly rainfall amounts expressed in mm.

4.4.3.2 Spring discharge measurements

The spring discharges were obtained from data archived by the community management teams. The Nuu area is characterized by several springs as shown in Figure 3-2.The spring discharges were measured on site using a 20 litre jerican and a stop watch to estimate the time taken to fill the jerican with spring's water. Discharge was calculated using the following equations.

$$T_t = \frac{t_1 + t_2 + t_3}{3}$$ -- **Equation 2**

$$Q = \frac{20}{1000 * T_t}$$ --- **Equation 3**

Where:

t is the time taken for a 20 litre jerican to fill in seconds.

T_t is the average time taken for a 20 litre jerican to fill in seconds.

Q is the discharge calculated which is in m^3/s.

The measurements were done both during the rainy season when the discharge are highest and in the dry season when the flows were lowest.

4.4.4 Satellite Image Data

Remotely sensed data is available at global scales at a fine to medium resolution, and often for free or at a cost. Those data are increasingly being used in ecological studies (Chawla, et al., 2012). Remote sensing at regional and local scales has become an essential tool in wide areas. Landsat multi-spectral images have been a successful application for production of land cover maps (Vogelmann and Rock, 1988; Hall, et al., 1991; Coppin and Bauer, 1994), monitoring change in ecosystem condition (Lambin, 1998; Weng, 2002), monitoring deforestation and protected forest areas (Potapov, et al., 2008). The Landsat programme is the longest-running enterprise for acquisition of satellite imagery of the Earth Resources Technology Satellite which was launched on July 23, 1972 (Vogelmann, et al., 2004; Kauth, et al., 1976). All the four series of the Landsat data images were created into global data set - Global Land Survey (GLS) Landsat records (Fuller, et al., 1994). This digitized information is down linked to ground stations, processed, and stored in a data archive.

The methodology used in this study includes the following stages: image pre-processing, the design of classification scheme, image classification, accuracy assessment and analysis of the land cover changes in Landsat. The dates of the Landsat images were chosen to be far apart as possible to study vegetation cover degradation of the study area.

The methodology outlined in Figure 4-1 shows the normal procedures used for land-cover change detection. The Landsat images for 1980, 1990, 2000 and 2010 time series were used. Pre-processing steps involved geometric correction by re-projecting the images from the geographic coordinates to the UTM coordinate system. Radiometric correction was also applied to reduce atmospheric effects on spectral signatures of different land covers (Liu, et al., 2008).

Band setting was done to combine information captured by the satellite in different bands. Maximum likelihood algorithm for supervised classification was done using high resolution Google Earth images for 2000 and 2010. Ancillary data derived from the field and high resolution Google Earth images were used to cross-check how accurate the classification reflect the land-cover maps. This involved use of random points such that each point has an equal chance to fall in each class. The land cover maps were thereafter derived and after post-processing, statistics for change detection were derived (Fuller, et al., 1994).

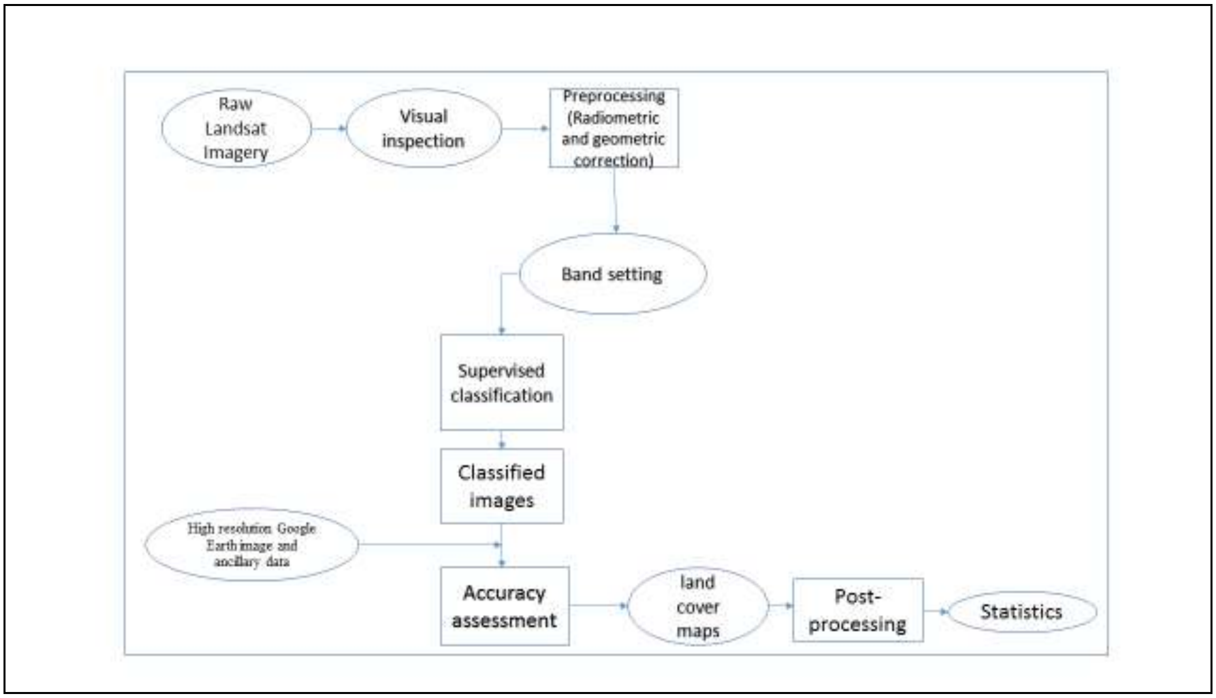

Figure 4-1: Process used to get Landsat images (Liu, et al., 2008).

4.5 Secondary data

Secondary data was acquired from the pre-existing records from Tanathi Water Services Board (TAWSB) and Water Resources Management Authority (WARMA) and reports of other studies done in the study area. The rainfall data collected from the Water Resources Management Authority (WARMA) offices was supplemented by data collected from Kenya Metrological Department (KMD) in Kitui. Unpublished data and information on the Nuu Hills catchment was obtained from Kitui County government offices and Water Resources Management Authority (WARMA) in Kitui regional offices. Documents from WARMA involved information pertaining to the current protection of the catchment that may be ongoing and also the policies that have been put in place. The data from the previous study by Kitui County Government was used to supplement the data that the author collected in the field. This allowed the author to boost the amount of data that was available for analysis, and also for counterchecking the accuracy of results.

4.6 Method of data analysis

The data collected were analyzed using the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel statistical package. Quantitative data was coded, processed and analyzed. Various quantitative statistical methods that were used including arithmetic mean, regression and correlation. Those are described in the following sections.

4.6.1 Measures of Central Tendency

Measures of central tendency were used in analysis of data. The arithmetic mean was obtained by summing up the values and then by dividing by the number of values as shown in the following equation (Lane, 2008).

$\overline{X} = \frac{\sum x}{N}$ -- **Equation 4**

Where;

$\bar{x}$= Arithmetic mean

$\sum x$ = Sum of values in the series

N = Number of values in the series

Equation four was used to quantify different quantitative indicators although some averages were expressed in terms of percentage (Lane, 2008).

4.6.2 Regression Analysis

A general goal of regression analysis was to estimate the association between one or more independent variables and a single dependent variable. As the names imply, a dependent variable was presumed to depend or be systematically predicted by the independent variables. In the study, the parameters or variables that were analyzed using this method are rainfall and spring discharges. The regression equation is presented by equation 5 (Lambin, 1997).

Y= bx + a + e --- **Equation 5**

Where;

y = value of the dependent variable.

x = Value of the independent variable.

A–a constant- equals the value of y when the value of x=0 b –the coefficient of x- the slope of the regression line; how much y changes for each one-unit change in x.

e = Error term; the error in predicting the value of y

4.6.3 Correlation Analysis

The correlation coefficient (r) was used to measure the degree of association between the two variables (Armitage et. al., 1990). Its value may vary between -1 and +l. If all observed data fall on a straight line, there is a perfect correlation and y is said to be totally dependent on x. The value of r would be either +1.0 or -1.0. If it were +1.0, y would increase as x increased (positive slope of the regression line). If it were -1.0, y would decrease as x increased (negative slope of the regression line (Gefen, et al., 2000). The other important parameter in this analysis is the p-value which shows the significance of the regression equation in predicting the dependent variable using the independent variable. According to Gefen and other researchers in 2000, the smaller the p-value the more confidence we get of using the regression equation. The regression equation is significant if the p-value is less or equal to 0.05. The correlation coefficient was computed using Equation 6.

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}}$$ ----------------------- **Equation 6**

Where;

r is correlation coefficient

n is the number of observations.

x and y are variables tested.

The quantity r, called the linear correlation coefficient, measures the strength and the direction of a linear relationship between two variables.

4.6.4 Hypothesis testing with Analysis of variance (ANOVA).

A hypothesis is a guess about the study and in our case the guess is the relationship between forests springs decline in production. The hypothesis in this study is testable, either by experiment or observation. Hypothesis testing in statistics is a way of testing the results of a survey or experiment to see if there are meaningful results (Phillips, et al., 1988). Basically hypothesis is tested to know whether the research results are valid by figuring out the odds that the results have happened by chance. If the results may have happened by chance, the experiment won't be repeatable and so has little use.

ANOVA is a statistical method that stands for analysis of variance. It tests the hypothesis that the means of two or more populations are equal. ANOVAs assess the importance of one or more factors by comparing the response variable means at the different factor levels (Obuchowski, et al., 1995). The null hypothesis states that all population means (factor level means) are equal while the alternative hypothesis states that at least one is different. To perform an analysis of variance (ANOVA), you must have a continuous response variable and at least one categorical factor with two or more levels. It also requires data from approximately normally distributed populations with equal variances between factor levels (Phillips, et al., 1988). However, Analysis of variance (ANOVA) procedures work quite well even if the normality assumption has been violated, unless one or more of the distributions are highly skewed or if the variances are quite different. The procedure works by comparing the variance between group means versus the variance within groups as a way of determining whether the groups are all part of one larger population or separate populations with different characteristics.

CHAPTER FIVE

RESULTS OF THE STUDY

5.4 Introduction

This chapter is focused on the presentation of the results of the study. The chapter specifically presents details on the results of the analysis of data using Statistical Package for the Social Sciences (SPSS) and Ms Excel as well as the analysis of satellite imagery acquired from Google earth and Landsat. This is complemented by use of maps that were created using Geographical Information System (GIS).

5.5 Rainfall variability

Rainfall in the study area shows significant inter-annual variability. Figure 5-1 shows how the rainfall variability in the study area. Rainfall received in the study area was higher in 1990, 1994, and 1997 as compared to rainfall received within the same area on 1987, 1996, and 2000 as shown in Figure 5-1 below. The highest precipitation received in 1997-1998 period was about 1600mm and this was associated to El-Nino southern oscillation phenomena.

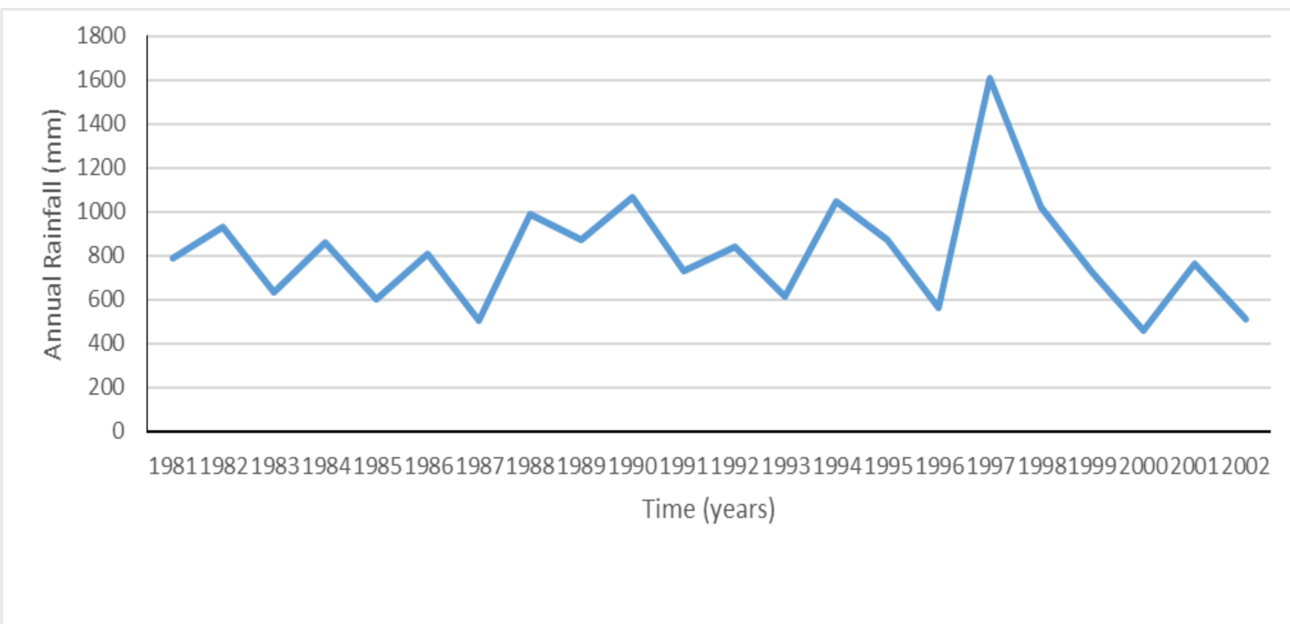

Figure 5-1: Rainfall variability in Nuu region in the period between 1981 and 2002 (data from Kenya Metrological Department).

There was a noticeable decrease in annual rainfall amount from 1981 to 1987 and from the year 2000 but a slight increase in annual rainfall was noticed between 1987 and 1990. There was a sharp and shooting increase in 1997 and 1998. This was attributed to occurrence of El-Niño in 1997-1998. During this period, the region received a relatively higher rainfall amount than normal.

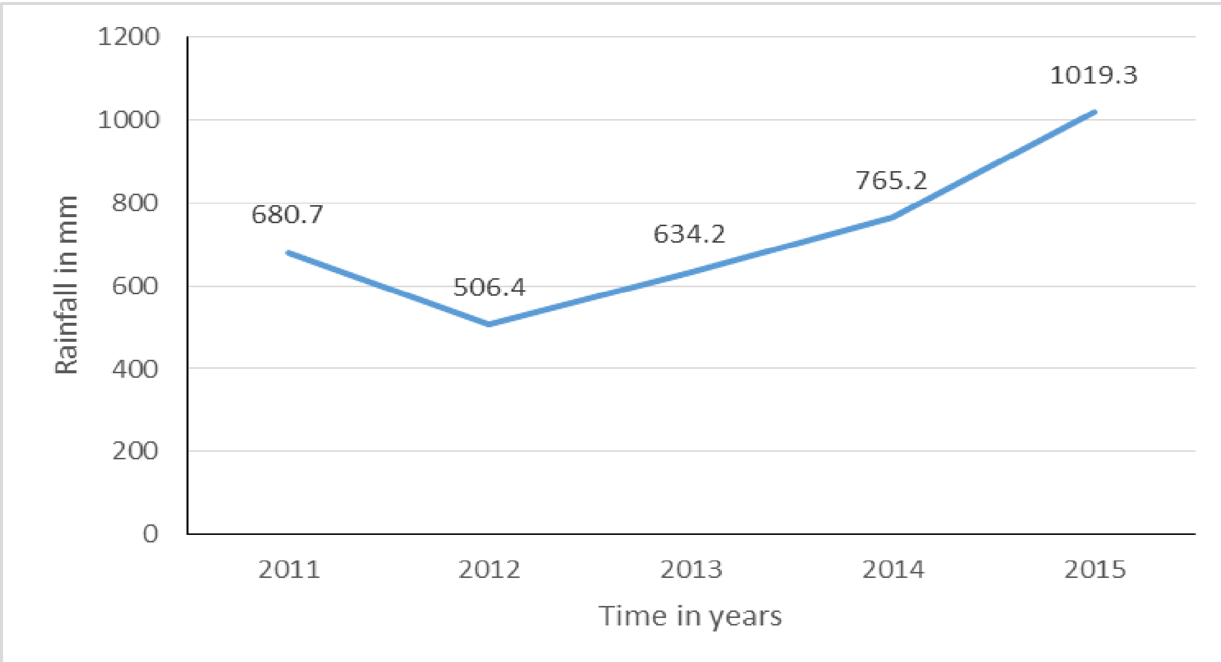

Figure 5-2: Rainfall variability in Nuu region in the period between 2011 and 2015 (data from metrological department).

Figure 5-2 shows an average monthly rainfall distribution for the Nuu region for the period between 2011 and 2015. Rainfall in 2012 was relatively lower as compared to the rest of the years. An increase in annual rainfall amounts was noted after 2012. This was attributed to the El-Niño rains that were experienced in the region in the period between 2014 and 2015. Rainfall distribution for the different years in terms of months is bimodal distribution as the highest amount of rainfall was mainly concentrated within two rainy seasons (Figure 5-3). The highest rainfall were received during the short rainy season between the months of November and December while the annual mean rainfalls were relatively low during long rainfall season months of April and May.

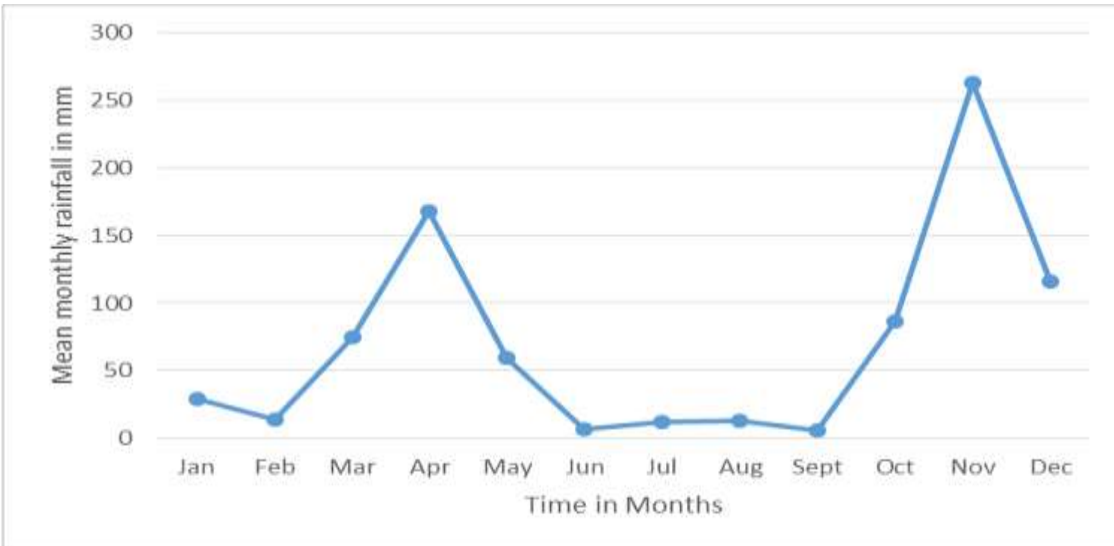

Figure 5-3: Monthly rainfall variability in Nuu region in the period of study (data from metrological department).

Figure 5-4 shows the rainfall distribution in Nuu region for the period between 1980 to 2015. The trend line in the figure shows that the rainfall amount is decreasing with time. The decrease in rainfall could also be attributed to climate change.

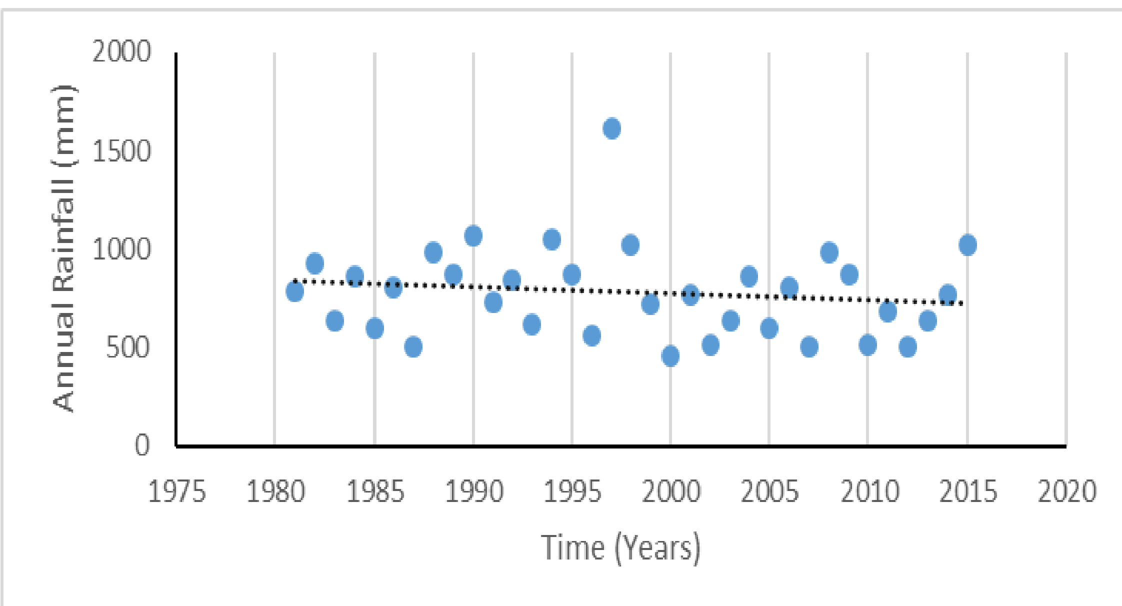

Figure 5-4: Linear graph for rainfall distribution in Nuu region for the period between 1980 to 2015(data from Metrological Department).

5.6 Variability in springs discharge

There is evidence of decrease in the discharge of springs between 1985 and 1995. This is based on data collected from springs shown in Figures 5-4 and 5-5. The discharge was at its pick in the years between 1990 and 1995. The spring's production was higher in period between 1985 and 1990. The trend line of figures 5-4 and 5-5, gives a clear evidence that the springs discharge is declining in the Nuu hills.

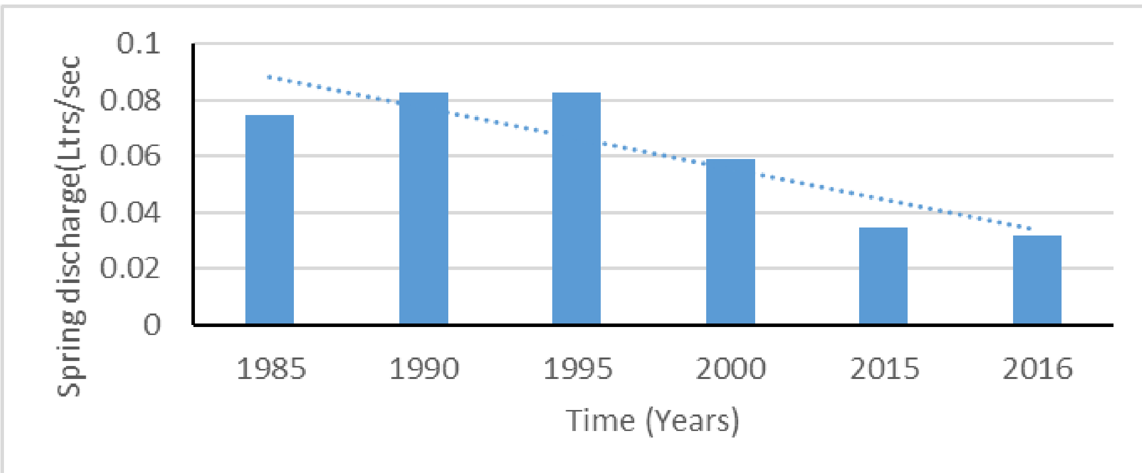

Figure 5-5: Kavui spring discharge in Nuu catchment (Source, Author 2016).

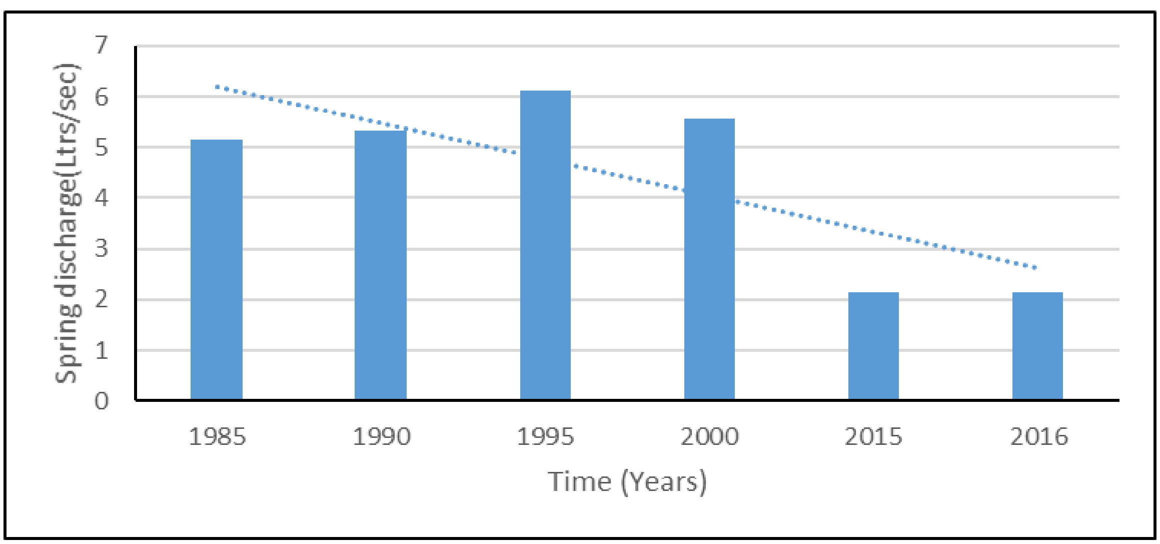

Figure 5-6: Mola spring discharge in Nuu catchment area (Source, Author 2016).

The highest overall discharge in the springs observed was for Mola, Kaunzuu and Kiwani springs, respectively while the lowest overall discharges were for Kanyululuni, Kyatuka, Minyiini and Mutaitho springs (Table 5-1 and 5-2). The spring discharge in the Nuu area is such that the productions from individual springs are decreasing. The springs discharge was relatively high in 1980s and there is a significant decrease from 1995 towards the year 2016.

Table 5-1: Springs location in the Nuu hill and their discharges both in wet and dry season

No	Name	Position (GPS)	Altitude (M)	Average yield wet season (Ltrs/Sec)	Average yield dry season (Ltrs/Sec)	Remarks
1	Kavui	423741/9886651	801	0.052701	0.031621	Gauged
2	Makaveti	424099/9886619	868	0.21312	0.127872	Gauged
3	Mola	424605/9887101	726	3.621876	2.173126	Gauged
4	Wikya	425301/9886228	784	0.258732	0.155239	Gauged
5	Kiwani	422211/9885745	970	1.71556	1.029336	Gauged
6	Nuu	428554/9883127	675	0.989315	0.593589	Gauged
7	Kanyululuni	421609/9886397	872	-	nil	Dry
8	Kyatuka	424638/9887014	920	-	nil	Dry

Table 5-2: Springs for Mutaitho hill and their discharges both in wet and dry season

No	Name	Position (GPS)	Altitude (M)	Average yield wet season (Ltrs/Sec)	Average yield dry season (Ltrs/Sec)	Remarks
1	Kiviu	422371/9879845	1171	0.666445	0.399867	Gauged
2	Kaunzuu	422021/9877646	863	2.172735	1.303641	Gauged
4	Minyiini	423397/9878933	1062	0.082181	0.049308	Gauged
5	Kasyongala	424001/9879580	952	0.740878	0.444527	Gauged
6	Mutaitho	423208/9879369	1152	-	nil	Dry

The decrease in spring's discharges can be attributed to the increasing degradation of Nuu hills catchment area since rainfall in 1995 was within the normal rages (Figure 5-1). However subsequent decline in rainfall could also explain the reduction in spring's discharges. From Figure 5-4 and 5-5 seems to have high springs discharge in 1995 within Nuu catchment, this can be attributed to increase in rainfall which is seen in figure 5-1 starting from year 1994 towards 1998. Local communities had their few on the variability of springs discharges as they also mentioned the years they felt the springs were highly productive than current time during the study. Figure 5-6 below showed that local communities thought that springs discharges on period between 1996 and 2000 and also between 1991 and 1995 were high. In the period between 1980 and 1985 and also between 1986 and 1990 had the lowest spring's discharges according to the respondents. The perception of the local communities in the area seemed to be consistent with the data presented in Figures 5-7.

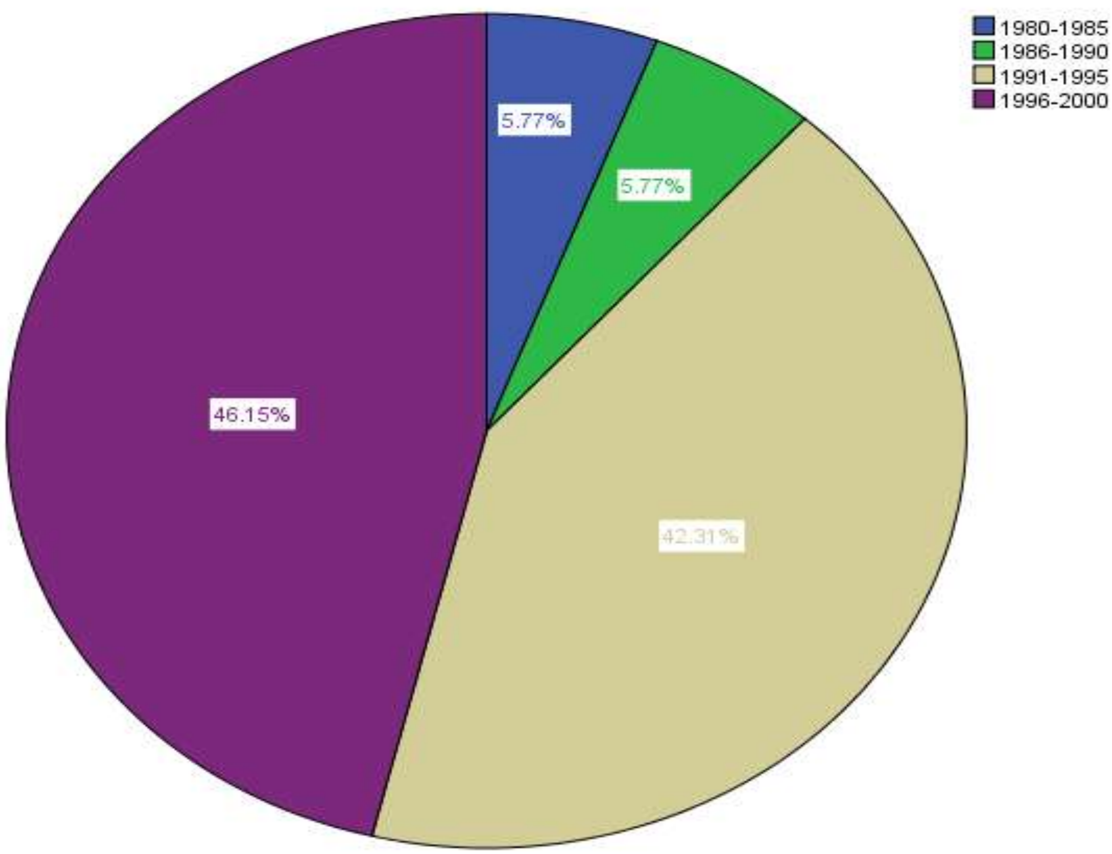

Figure 5-7: The distribution of the years when the discharge of the springs was high as per the community (Source: Author 2016).

5.7 Analysis of land cover changes using LANDSAT

Forests in the Nuu hills show a declining trend in the period between 1990 and 2010. Much of the forests followed a forest-shrub change trajectory where forests were degraded leaving behind shrubs. The end product of these changes is usually grasslands. Figures 5-8 shows the forest cover distribution in the area in the period between 1980 and 2010. The dark green color in the figure depicts the areas where the forest cover is highly concentrated while the chartered green portrays low forest cover. There is evidence of decline of forest cover from 1980 to 1990, but the greatest decline was noted in the period between 1990 and 2010 whereby the forest cover is almost diminished.

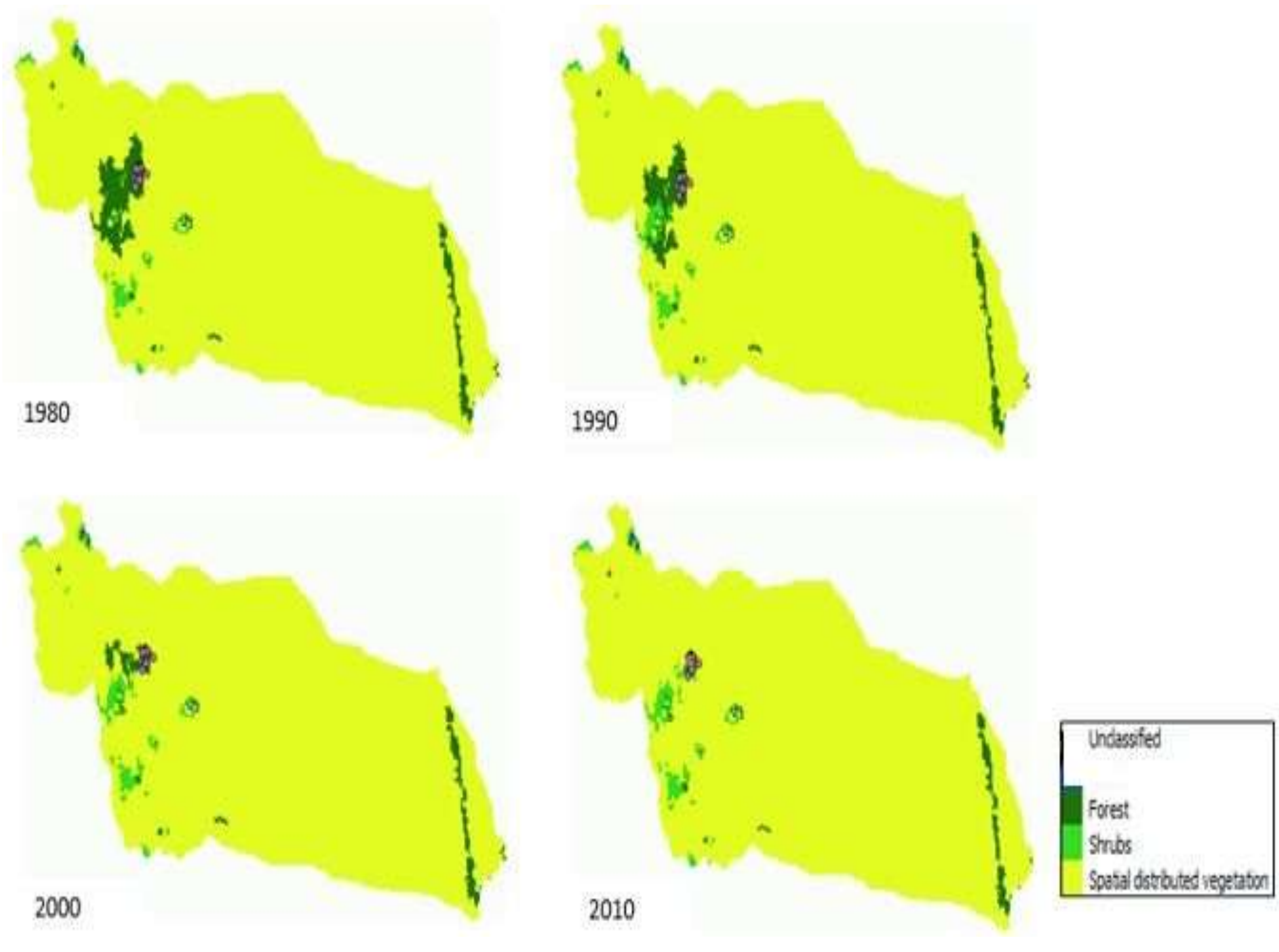

Figure 5-8: LANDSAT map for delineated catchment area of Nuu region for the years 1980, 1990, 2000 and 2010 showing forest cover changes (Source www.csiagr.org).

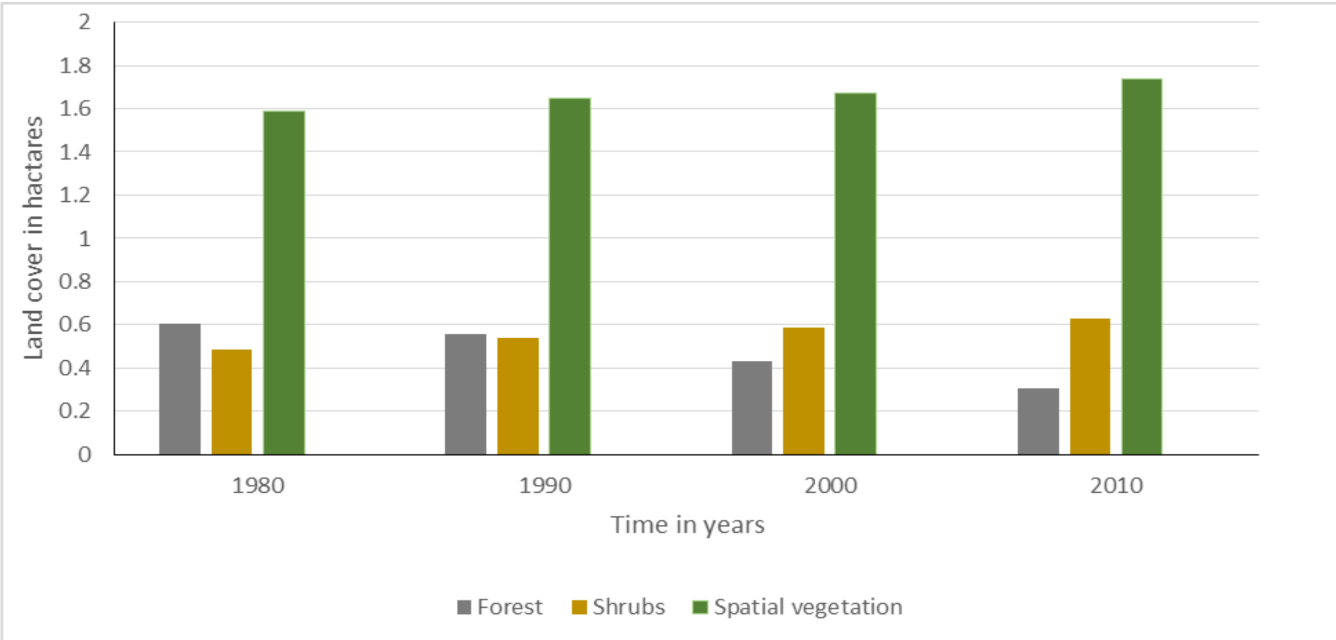

Figure 5-9: Analysis of land cover changes using Landsat data (Source www.csiagr.org).

Figures 5-9 presents the chart of distribution of forest cover changes in the period between 1980 and 2010. This figure also shows that the forest cover has decreased proportionally to increasing of shrubs cover and spatial vegetation distribution. The cause of the decrease in forest cover within the Nuu hills catchment area is suspected to be due to community activities within the area. These activities include logging, charcoal projects, clearing the land for crop production as the population increase and increase in livestock population as the rainfall is becoming unreliable hence community has turned their hope on livestock keeping.

5.8 Analysis of land cover changes using Google satellite image

Figure 5-10 presents satellite image for the town of Nuu and the location of the springs which are located in the region. The map shows the forest cover as the dark green and shrubs area as brown color during the year 2000. The map shows the locations where the vegetation cover is highly concentrated and the areas where the vegetation cover was low in the year 2000. Forest concentration is high at the hills more than at the low land reason suspected to be the act of forest gazzetment which were protected from human activities so the forest remained intact for some times unlike the low lands where the land was left for development and settlements meaning that the forest cover was disturbed for food production and livestock keeping.

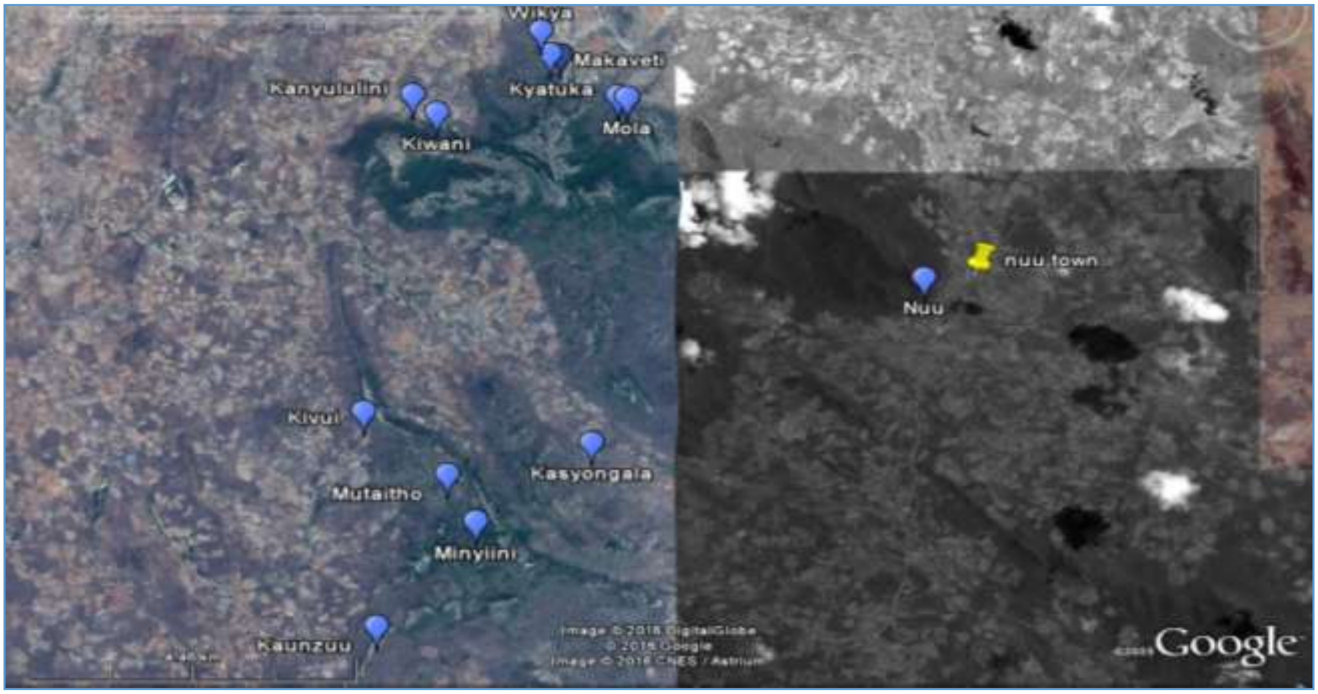

Figure 5-10: A satellite image for Nuu region for the year 2000 showing bare lands in the Nuu hills (Source: www.csiagr.org).

Figure 5-11: A satellite imagery for the Nuu region for the year 2016 showing vegetation cover on the two hills (Source: www.csiagr.org).

Figure 5-11 is a satellite image showing vegetation cover in Nuu and Mutaitho hills in the year 2016. The forest/ vegetation cover in the area is shown in dark green color while the brown parts are the shrubs or bare land. The analysis of the Google earth images, revealed that vegetation cover in the Nuu hills have changed. Also some hills regained vegetation cover in the year 2017 as compared to 2000. This could have been as a result of reforestation efforts by the community. However, this might require further research in view of the fact that there is a real decrease in stream discharge.

The human land use activities practiced within the study area are farming, livestock grazing and agro-forest. The reduction of forest cover was as a result of deforestation, encroachment on the recharge zones and over abstraction of water from the springs. Table 5-1 shows different activities practiced by the locals within the study area verses reasons for springs flow reduction.

Table 5-3: The distribution of activities practiced verses Reason for spring flow reduction Cross tabulation

		Reason for spring flow reduction			Total
		Reforestation	Encroachment by community	Over usage of water	
	Farming	4	3	4	11
Activities	Grazing	8	10	12	30
practiced	Agro-forestry	0	0	1	1
		0	0	1	1
Total		12	13	18	43

Perception of local community with regards to the root cause of the reduction in the flows of springs discharges was somewhat divided. Most of the people believe that the decline is due to deforestation while other believes it is due to community encroachment on hills. However, most of them believe that the major cause of decrease of the flow of springs is over usage of the springs water (Figure 5-12). This gives the strength to the cross tabulation of activities practiced and the root cause of springs flow reduction, as shown in Table 5-3.

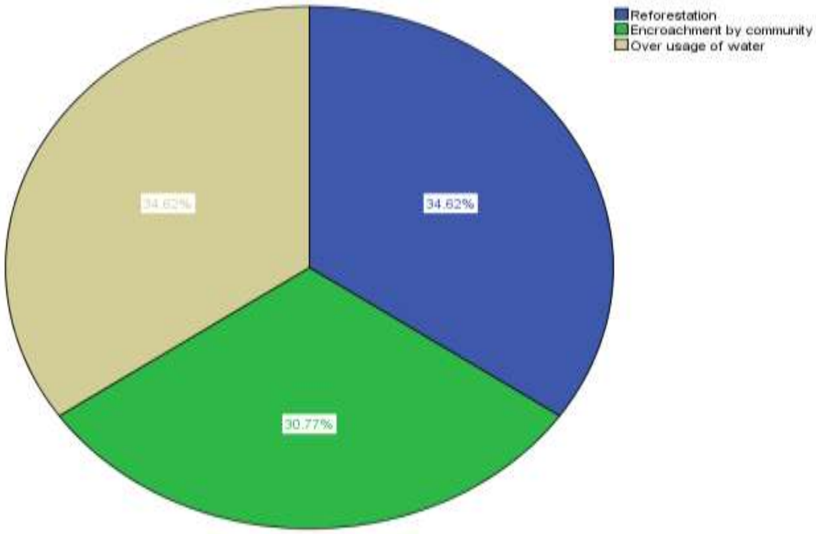

Figure 5-12*:* The distribution of the local community view on the root cause of the reduction of the springs discharge in Nuu hills

Source of water for Nuu communities is mostly springs (Table 5-4). There are however, other sources of water in the area such as wells and rivers, although they are regarded as the major sources of water for the Nuu region communities. The springs are sources of water for 75% of the local communities while seasonal rivers and shallow wells contribute 25% of the water used by the local community. The springs are regarded as more reliable source of water due to the fact that spring water is less contaminated and the volume shows less variability (Table 5-4).

Table 5-4: The distribution of the sources of water for the residents of Nuu location

		Frequency	Percent	Valid Percent	Cumulative Percent
	River	6	11.5	12.5	12.5
	Springs	36	69.2	75.0	87.5
	A well	6	11.5	12.5	100.0
	Total	48	92.3	100.0	
	Dam	4	7.7		
Total		52	100.0		

Table 5-5: The distribution of the Community views on common knowledge of relationship between forest and water

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	18	34.6	34.6	34.6
No	34	65.4	65.4	100.0
Total	52	100.0	100.0	

There is a very little understanding among community of the importance of forests. Table 5-5 shows that most of the local community in the Nuu region was not aware of the relationship between water and forest during the time of questionnaire administering. Only about 35% are aware of the relationship between forest and springs production while 65% are not. This shows that there is need for education or awareness creation among the local communities so as to protect the catchment area in Nuu region.

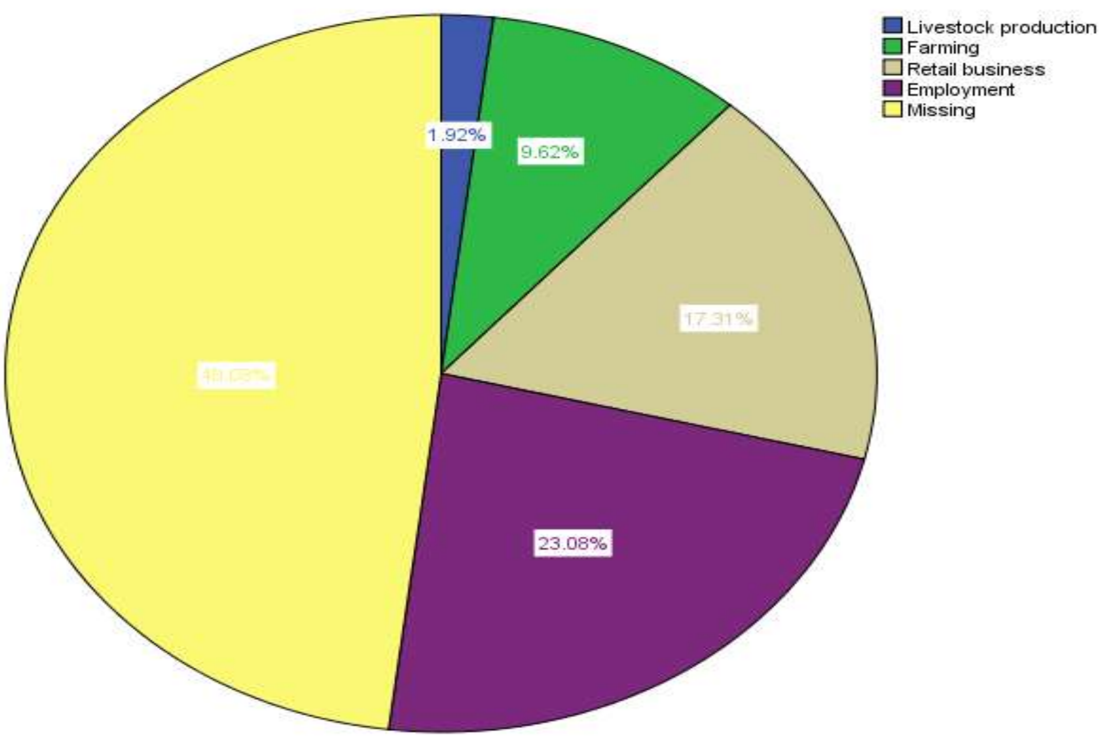

Figure 5-13: The distribution of the sources of income among the communities in Nuu region

Figure 5-13 shows that majority of the local community members (48%) had no definite source of income though the region has a good number of the locals in the employment sector. The percentage of the locals who are in the farming business is only 9% of the total population while those in the retail business are 17%.

Table 5-6: The distribution of the different initiative to conserve forest for more spring production

		Frequency	Percent	Valid Percent	Cumulative Percent
	Planting more trees	20	38.5	60.6	60.6
	Best farming practices	13	25.0	39.4	100.0
	Total	33	63.5	100.0	
	Nothing	19	36.5		
Total		52	100.0		

The results of the study also showed that 36.5 % of the local community did not participate in activities related to the conservation of the forest in the Nuu hills. However about 38.4 % were actively involved in forest conservation activities aimed at restoring the forest cover in Nuu hills (Table 5-6). The Figure also shows that 25% of the locals are also involved in best farming practices.

The plate 5-1 below shows bare land near the Mola spring which has been degraded through cutting of trees for charcoal production. This has led to large areas of exposed land within the hills with very little vegetation cover. There has also been increased soil erosion problem in the catchment area. This has led to high sediment transport to seasonal streams such as Enziu River. The river water is highly turbid due to high concentration of suspended sediments derived from the degraded Nuu hills.

Plate 5-1: Human impacts in the study area in the period when we are taking data which is late 2015, take on February 2016 (Source, Author 2016).

The high turbidity of water reduces the use of the river water. The river flow is also rapid such that it dries up within few hours after a rainfall event (Plate 5-2). The rapid flow of seasonal rivers is attributed to the lack of sufficient vegetation cover on the catchment areas like Nuu hills for this study. There is thus very little of rainfall on the highly degraded hills as the process of rainfall formation and falling to the ground is formed by a process of the combination of vegetation and water masses.

Plate 5-2: Enziu River during the rainy season. (Source, Author 2016).

5.9 Relationship between deforestation and springs production

Table 5-7 presents the results that were obtained for the relationship between activities practiced within the study area and causes of springs discharge decline. The study tested the relationship between activities practiced at Nuu region and causes of spring flow reduction. The correlation coefficient (r) for the above relationship was 0.25 which is rather low although it indicates positive relationship. This could be attributed to the limited data that was collected during the field survey.

Table 5-7: The results of correlation analysis of the relationship between activities practiced on land and cause of springs flow reduction.

		Activities practiced	Reason for spring flow reduction
Activities practiced	Pearson Correlation	1	0.211
	Sig. (2-tailed)		0.175
	Sum of Squares and Cross-products	19.860	10.837
	Covariance	0.473	0.258
	N	43	43
Reason for spring flow reduction	Pearson Correlation	0.211	1
	Sig. (2-tailed)	0.175	
	Sum of Squares and Cross-products	10.837	155.077
	Covariance	0.258	3.041
	N	43	52

Figure 5-14 below shows the age groups of the respondents to whom the questionnaires were administered against their net monthly incomes. The majority of the respondents were within the age group of 31 to 40 years and 41 to 50 years. Monthly incomes for the respondents in relation to their genders showed that female respondents had a monthly salary in all the categories this means that female respondents who were interviewed were employed while their male counter parts were not. This could give an impression that, there were other different sources of income which could be farming, livestock production and retail businesses.

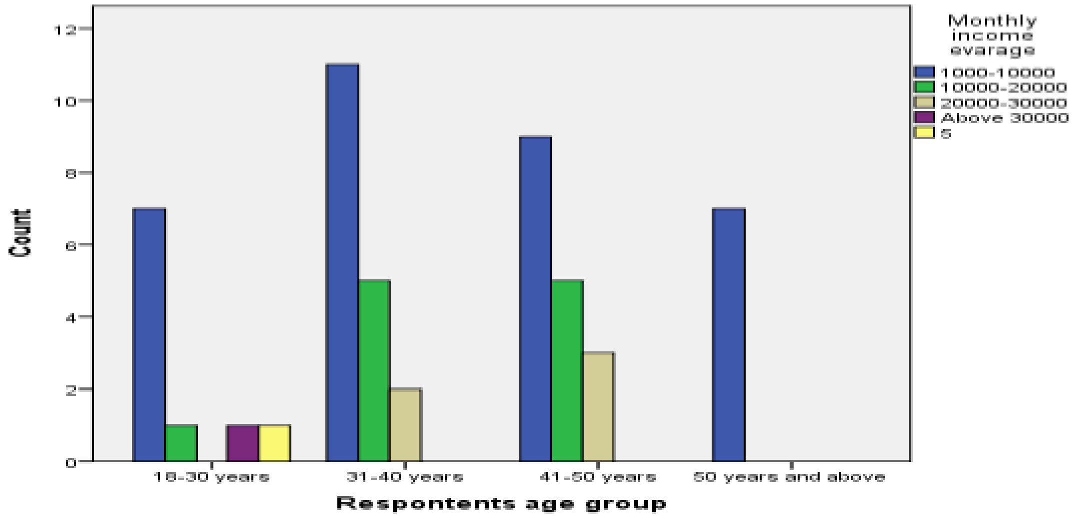

Figure 5-14: The distribution of the different age groups of the respondents against the monthly incomes

Majority of the respondents had attained primary and secondary education levels. The percentage of those who had college and University education levels were very low. Activities practiced by most of the respondents are farming, grazing and agroforestry. The different activities were then tabulated against the different genders of the respondents. The results showed that women are more active in livestock keeping than their male counterpart (Figure 5-15).

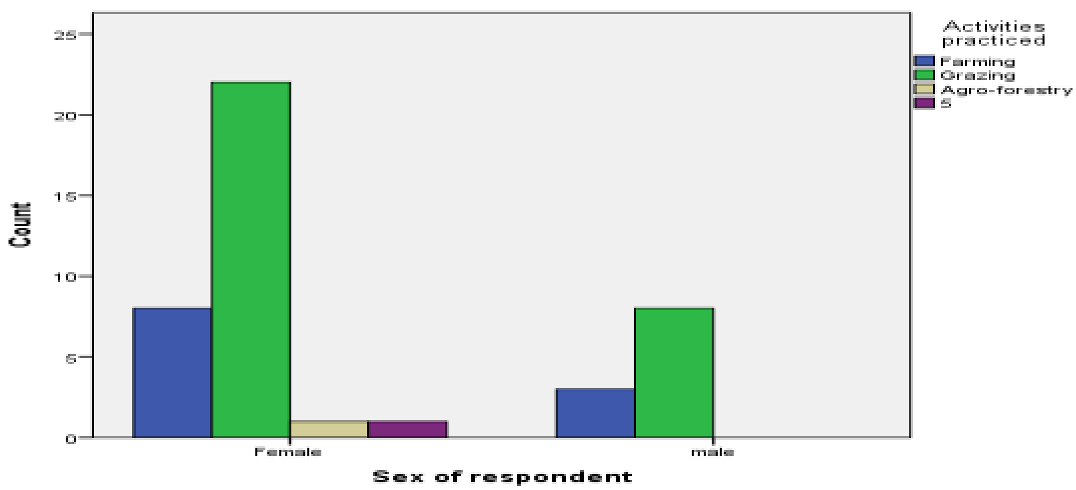

Figure 5-15: The distribution of the different genders against the different activities that are practiced by the locals.

Table 5-8 below shows the frequency of awareness creation among the community of Nuu region. More weight rested on quarterly awareness creation which is 70%. This information was provided by leaders in the region. It's clearly showing that after every quarter of the year there is an attempt to educate the local community on importance of conservation of the forest cover among other natural resources.

Table 5-8: Distribution of percentages on how community education is created.

	Frequency	Percent	Valid Percent	Cumulative Percent
Monthly	2	20.0	20.0	20.0
Quarterly	7	70.0	70.0	90.0
Yearly	1	10.0	10.0	100.0
Total	10	100.0	100.0	

From the study it also emerged that there existed initiatives to promote reforestation (Figure 5-16). These initiatives includes awareness campaigns and trainings of communities on issues related to forests conservation.

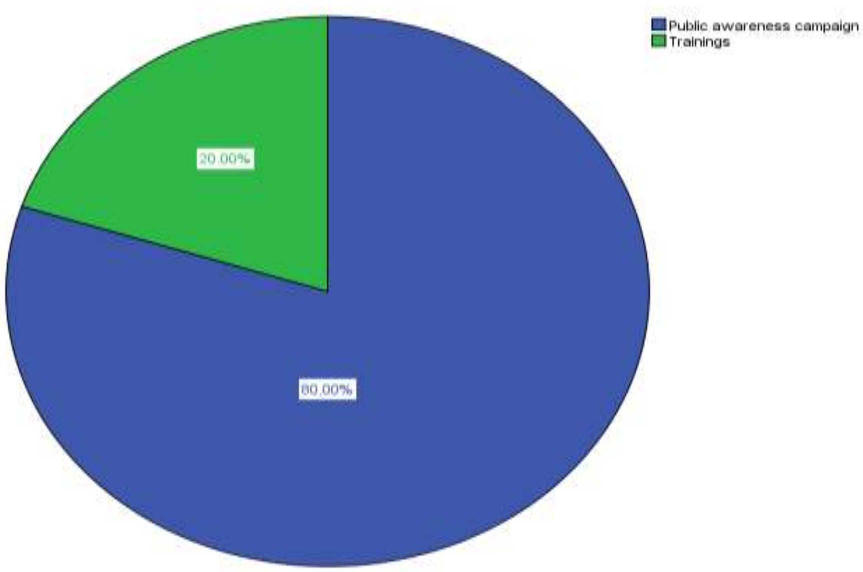

Figure 5-16: The distribution of the reforestation promotion means to community.

Table 5-9: The distribution of the techniques used in awareness creation campaigns.

	Frequency	Percent	Valid Percent	Cumulative Percent
Recognize and applaud water conservation measures	3	30.0	30.0	30.0
None	7	70.0	70.0	100.0
Total	10	100.0	100.0	

Based on the results presented in Table 5-9, techniques used in awareness creation at Nuu location are mostly recognition and applauding water conservation measures which is at very minimal percentage of 30%.

Table 5-10: Community views on the list of stakeholders on the ground dealing with springs issues.

	Frequency	Percent	Valid Percent	Cumulative Percent
NGOs	2	20.0	20.0	20.0
Community members	3	30.0	30.0	50.0
Gok/parastatals	2	20.0	20.0	70.0
missing	3	30.0	30.0	100.0
Total	10	100.0	100.0	

In Table 5-10, it was noted that NGO's constitutes 20% of the stakeholders who were involved in conservation activities, meaning that the government contribution to the conservation issues in Nuu region is 20%. This leaves a large gap on awareness creation among government parastatals. Community groups who are trained as trainers are taking the bigger part in awareness creation among the communities.

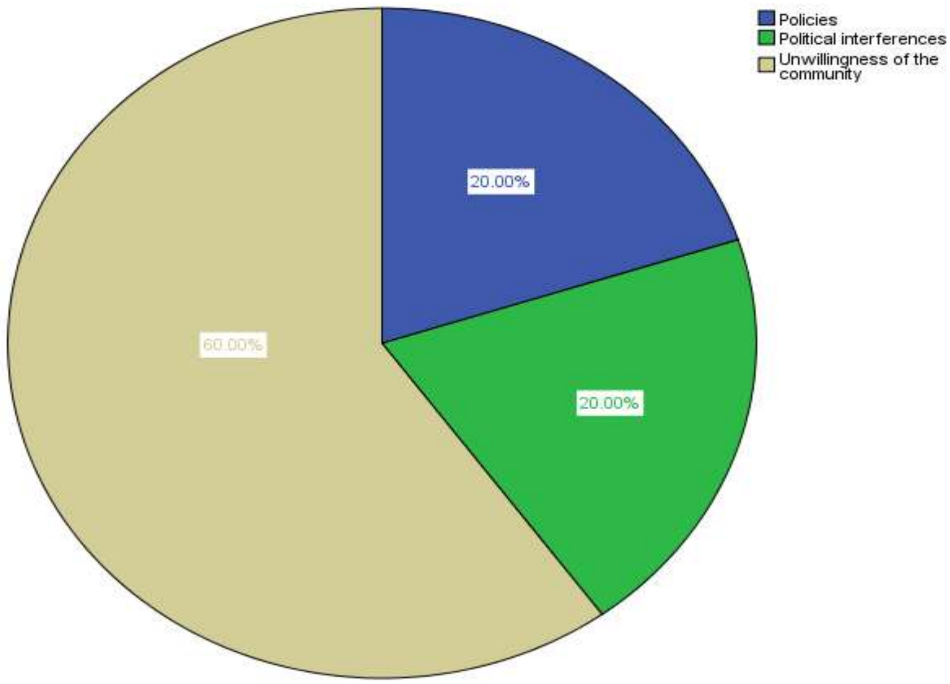

Figure 5-17: Distribution of the challenges faced in awareness creation as per the community.

Figure 5-17 shows that there exist problems when creating awareness to communities on how to conserve forest. The biggest problem faced is unwillingness of the community to receive information. Policies and political interferences take a small percentage of the totals problems expressed by the local community.

Table 5-11: Respondent's ideas on initiatives taken to restore springs production

	Frequency	Percent	Valid Percent	Cumulative Percent
Ground water recharging	1	10.0	10.0	10.0
protection of water sources	7	70.0	70.0	80.0
Ground water recharging	2	20.0	20.0	100.0
Total	10	100.0	100.0	

Table 5-12: Respondent's ideas showing the long-term and the short-term goals.

	Frequency	Percent	Valid Percent	Cumulative Percent
Relocation on upper hill settlement	7	70.0	70.0	70.0
Trainings	3	30.0	30.0	100.0
Total	10	100.0	100.0	

Tables 5-11 and 5-12 presents' existence of some initiatives applied to restore springs production. Those include protection of water sources and ground water recharging. Most of the respondents (70%) felt that the relocation from the upper hill or recharge zones settlement would be more effective in reducing degradation of the Nuu hills forest.

Table 5-13: Cross tabulation of respondent's age group and monthly income average per age group.

		Monthly income average					Total
		1000-10000	10000-20000	20000-30000	Above 30000	5	
Respondents age group	18-30 years	7	1	0	1	1	10
	31-40 years	11	5	2	0	0	18
	41-50 years	9	5	3	0	0	17
	50 years and above	7	0	0	0	0	7
Total		34	11	5	1	1	52

Table 5-13 above presents the age group analysis of the respondents who were administered with questionnaires to give all the above responses. Most of the respondent's age raged between the age groups of 31-40 years and 41-50 years.

5.10 Hypothesis testing with analysis of variance (ANOVA).

This study sought to test the relationship between forests springs decline and the degradation of Nuu hills forest.

5.10.1 Results of ANOVA in hypothesis one

It stated that there was no significant relationship between spring discharges and the rate of deforestation in Nuu hills catchment.

Table 5-14: Analysis of Variance results (ANOVA)

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10413799	2	5206899	19604.35	4.2E-17	4.256495
Within Groups	2390.393	9	265.5992			
Total	10416189	11				

Table 5-15: Summary of analysis of variance.

Groups	Count	Sum	Average	Variance
Year	4	7986	1996.5	235.6667
Forest cover area(ha)	4	1.902	0.4755	0.018262
Annual average Springs production	4	163.36	40.84	561.1127

Table 5-15 are results under the heading "SUMMARY" simply provides us with summary statistics for each of your samples. Table 5-11 are results of the ANOVA test which are provided under the heading "ANOVA." (F is variance ratio)

Table 5-14 gives a clear indication that, F > F crit (19604.35> 4.256495) meaning that we reject the null hypothesis. Therefore, we reject the null hypothesis. The means of the three populations are not all equal. At least one of the means is different hence there is significant relationship between spring discharges and the rate of deforestation in Nuu hills catchment. This results of the test means that for every increase in rate of deforestation impacts negatively on the spring's production.

5.10.2 Results of ANOVA in hypothesis two

It stated that there was no significant relationship between spring discharges and rainfall variability in the Nuu hills catchment.

Table 5-16: Analysis of Variance results (ANOVA)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10052181	2	5026091	11345.86	4.92E-16	4.256495
Within Groups	3986.902	9	442.9891			
Total	10056168	11				

Table 5-17: Summary of analysis of variance.

Groups	Count	Sum	Average	Variance
Year	4	7986	1996.5	235.6667
Mean Rainfall per year	4	277.6	69.4	532.1878
Annual average Springs production	4	163.36	40.84	561.1127

Table 5-17 results under the heading "SUMMARY" simply provides you with summary statistics for each of your samples. Table 5-13 are results of the ANOVA test which are provided under the heading "ANOVA." (F is variance ratio).

Table 5-16 gives a clear indication that, F > F crit (11345.86> 4.256495) meaning that we reject the null hypothesis. Therefore, we reject the null hypothesis. The means of the three populations are not all equal. At least one of the means is different hence there is significant relationship between spring discharges and rainfall variability in the Nuu hills catchment. The rejected results of hypothesis testing of relationship between rainfall variability and spring discharges gives a clear indication that, rainfall variability affect the behavior of springs discharges in that, low rainfalls reduces the springs recharges with time and also high rainfalls increases the productions of springs within the study area.

CHAPTER SIX

DISCUSSION OF THE RESULTS

6.4 Introduction

This chapter presents the discussion of the results of the study. The discussions are centered on the influence of rainfall variability and forest degradation on spring discharges found in Nuu hills catchment area. The chapter also presents comparison of the results with the findings of other studies undertaken elsewhere in the world.

6.5 Rainfall Variability

Rainfall in Nuu hills shows significant seasonal and inter-seasonal variability. Figure 5-1 shows annual rainfall for Nuu location which shows that there is a significant fluctuation in average rainfall. There is evidence that, rainfall trend in the Nuu region over the past 22 years has been changing. However, there does appear to be a significant trend in the rainfall pattern for the years between years 1981 to 1998. There was a gentle increase in the rainfall received in Nuu region in the years from 1987 to1997. However, there was a decline in the period between 1998 and 2002. The reason for the high rainfall that was received in the period between 1997 and 1998 was attributed to the El-Niño Southern Oscillation phenomena. From 1981 to 1987, the average rainfall decreased significantly but there was an increase in the period between 1988 and 1990. Increase of average rainfall in 1994 and 1995 is noticed. The sharp rainfall increase in 1998 was followed by drastic decrease of the average rainfall in the following years. The years 1982, 1984, 1988, 1989, 1990, 1992, 1994, 1995, 1997 and 1998, were characterized by relatively high rainfall which was above the mean rainfall of 810mm pa for the last 22 years. The other years had a rainfall which was below the mean annual rainfall (Figure 5-2). In the period between 2011 and 2015, the average annual rainfall declined drastically within the first two years 2011 and 2012.There was an increase in the period between 2013 and 2015.

According to Singh, (1997) springs flow is significantly affected by spatial and temporal variability in rainfall and watershed characteristics which also depend on size and shape of a watershed and its hydrological response. Hobbs,et al. (1991) noted that impacts of rainfall reliability on watersheds is significant if the average rainfall input to the hydrological systems and the average time available for this precipitate to be redistributed into the water towers is well defined. The semi-arid regions of the world including Nuu region, our study area, are known for their unreliable rainfall, which has a large impact on the hydrology of the area and the water resources. This is also supported by Hobbs et al; (1991) and USAID (2000). In Nuu region the rainfall reliability is not constant hence we do not expect the springs flow to be constant. This agrees with the findings of Singh (1997) on the effects of rainfall variability and watershed characteristics. Figure 5-4 presents the linear analysis for rainfall distribution in Nuu region for the period between 1981 to 2015 whose trend line shows that there is a decline in rainfall distribution within the study area.

6.6 Relationship between spring discharge and rainfall

The spring discharge in the Nuu Hills has been reducing significantly. Figures 5-5 and 5-6 shows a clear decline of the spring's discharges of the two springs (Kavui and Mola) of which the same trend is seen in other springs within the study area. Before the year 2016, there was a severe reduction in springs discharge. Tables 5-1 and 5-2 shows the data collected from the practical part of the thesis in measuring the springs discharge per hour, which indicates a very minimal spring's production at that time of data collection. Figure 5-7 shows the view of the local community in terms of the years when the spring flows were high. The periods between 1990 and 2000 had the highest spring discharges. The perception of the local communities is consistent with the rainfall data for the period between 1988 and 2000 (Figures 5-1).

6.7 Variability in land cover

The Land satellite data (LANDSAT) that was analyzed showed that the forest vegetation cover in the Nuu region was high in 1980's as compared with the year 2000 and 2010 (Figure 5-8). There was a decrease in the forest cover which is also evident in the satellite imagery that is shown in Figure 5-10 and 5-11 within the same period. Main causes of forest cover changes are mainly deforestation in the area due to felling of trees for farming or business of charcoal burning and selling. This is also in consistent with research results of Chiwa (2012) on the effects of land use on land cover changes. From the questionnaire survey, it became clear that the activities that are practiced by the locals are mainly farming, grazing, and agroforestry (Table 5-

3). There is a large proportion of the locals that are involved in livestock grazing and farming activities. These activities have contributed to the degradation of the Nuu hill forests.

The forest cover for the Nuu region in the periods between 2000, and 2016 (Figures 5-8, 5-10 and 5-11) portrays a noticeable increase in the forest cover. This might be due to natural vegetation following the eviction of people living above the cut line of the gazetted area in 2010 (County report 2015). The perception of the locals is that the spring discharge is reducing due to encroachment by the local communities near the forest areas, over-usage of the spring water and also as a result of deforestation (Table 5-3). These observations are consistent with the data that was obtained from the LANDSAT images (Figures 5-8). The springs are the main sources of water for the locals and hence their continued existence is paramount to the local community in the Nuu region (Table 5-4). The questionnaire survey also showed that local communities were not fully aware of the relationship between the forest cover and water sources (Table 5-5) and this was noted to have been contributed by the negligence of the local communities in total clearing of the existing forest cover and lack of interest to participate in reforestation initiatives. With regard to the effect of ownership of land, most of the local communities were not owners of land as they have inherited the land from their fore fathers who owned the land by settlement and not land commission adjudication of land. Therefore the land tenure system can be considered to be a detrimental factor in as far as degradation of catchment areas is concerned. The main sources of income for the locals in the area are mainly employment, retail business and farming (Figure 5-13). The locals also pointed out that majorly of them were not involved in conservation of the forests in the Nuu hills (Table 5-6). A small percentage of the local community were involved in the planting of trees and the application of best farming practices such as terracing which may have contributed to vegetation cover increase between 2010 and 2016.

6.8 Impacts of deforestation in Nuu catchment

Forests constitute water towers within Nuu hills region. The forests have a longer root depth and they facilitate increases in infiltration rates which in-turn accelerates ground water recharge. Any changes in forest cover leads to change in groundwater flow systems and springs discharge capacity (Eldridge et al; 2005).

Nuu and Mutaitho hills act as a natural water tower for local communities of Nuu region. These forest stores water during the rainy season and releases it during the dry season. Deforestation has been linked to increasing magnitude and frequency of runoff events and reduced base flows (Liu et al; 2008). Deforestation also destroys the habitat for vast variety of species, and threatens the welfare of the local communities who rely on forests for their livelihoods (Liu et al; 2008). Disrupting the forest's role in storing and distributing water to outlying areas, would make disaster come faster by destroying the water cycle hence protecting the water towers is vital (Tiwari et al;2012).

This study has shown that, majority of the people in the Nuu and Mutaitho hills were not involved in the listed economic activities. It is therefore likely that majority are involved in charcoal production. Thus, charcoal production activities in the area can be considered to be one of the leading causes of forest degradation in the Nuu hills. Local community of Nuu region seemed not to be aware of the importance of forest cover to a sustainable spring discharge. The local community does not feel any loose when clearing vegetation cover in the recharge zone of the springs. Signs of deforestation on Nuu hills catchment area is shown (Plate 5-1) as bare land, rain water tends to flow rapidly slowing down infiltration rate (Plate 5-2). This was also in consistent with the study done by Herlocker in 1979 on Land use and soil erosion in prehistoric and historical Greece which showed that, on bare land, runoff seems to move fast and infiltration rate was reduced. Plate 5-2 shows the flow of Enziu river that receives its water from the Nuu hills catchment. The flow in the river is rapid, which is the sign of reduced infiltration rate as a result of forest degradation.

6.9 Relationship between deforestation and spring discharge

Natural vegetation is generally characterized by high rates of infiltration compared with other types of land cover with a similar soil base. In natural forest there are usually several layers of vegetation thus the top layers of the soils are well protected and well structured (Eldridge, et al; 2005), any change from the natural growth to bare land, plantations, grazing land and crop production may reduce infiltration and the storage capacity of the soil. Forest cover allows the land underneath to steadily store and then release water slowly, though when an area has been deforested, rainwater tends to flow more quickly into rivers, increasing the likelihood of flash floods. Reduction of the land cover may have unforeseen impacts on the water cycle which can in turn alter spring discharge.

Table 5-7 showed the relationship between the activities practiced in the Nuu and Mutaitho hills and the causes for low spring discharges. The relationship is generally weak but positive. The cross tabulation results Figure 5-14 showed that, most of the community of age between 30 and 50 years earn very little income bringing a question about their sources of income. This also brings a suspicion that the locals were involved in illegal income generating activities in the Nuu hills. It was also possible to conclude that, the locals were involved in other income generating activity apart from the ones listed in the questionnaire that was administered. The results of questionnaire survey also showed that women in the Nuu region earn more income than their male counterparts. The female gender was the majority among the employed category of people in the area. It may be implied that the male gender is not willing to be employed for a monthly income as the forest resource is within their reach and they can engage themselves on charcoal business which is more lucrative and provided instant pay.

The analysis of the questionnaires showed that the main cause of the deforestation was as a result of the people not being fully aware of the relationship that exists between the forest and the spring discharges (Table 5-7). This is consistent with findings of Goudie (2013) who found that, for sustainable environmental resource management, local communities needed to be fully involved through awareness creation on sustainable forest resource utilization. The results of the study also showed that, the majority of those involved in livestock grazing and farming had at least attained a secondary level of education. Hence, it can be argued that jobless status is turning youth to other activities which are not environmental friendly like charcoal production among others. The results also showed that, local communities need to be enlightened on the effects of deforestation and the relationship between water and forest cover which is consistent with the result of study conducted by Githae (2012). From the study we also came up with the knowledge that majority of those who were involved in the farming and grazing were the women in the age bracket of 30 and 50 years with the majority being between 31 to 40 years (Figure 5-15). Our overall assessment is that, most women of this age have their children in either primary or secondary school hence they work hard to get food on the table and pay school fees for their children. From the analysis the results also indicate that, people in Nuu region mostly dependent on the springs for their day to day water needs, this means protection of those springs is important for their survival.

The analysis of the key respondents in the area showed that the frequency through which awareness is created among the community was mostly quarterly as shown in Table 5-8. According to Figure 5-16, the main way of promoting re-afforestation in the area that is currently in use is the creation of awareness campaign and the main technique that is used to create awareness is the recognition and applauding of water conservation measures undertaken by the local community. However based on Table 5-9, this measure only accounts for 30% as the remaining 70% of the people doesn't use any form of measures on the awareness creation. The stakeholders involved in awareness creation activities are mainly the GoK/parastatals and the NGOs with the community only accounting for a very small percentage (Table 5-10). The respondents in the area also showed that main challenge in awareness creation programme was the unwillingness of the community to accept the initiatives that were being introduced to them. The problem faced in awareness creation is a major hindrance in conservation (Figure 5-17). The initiatives implemented by different government bodies to control deforestation in the area were, (1) relocation of settlements from the water towers to down the hills and (2) training the community on reforestation to reclaim the lost forest resource. This is also consistent with Allen, et al (1985) whose recommendation for diminishing water towers was protection of the water resources mainly by use of different ground water recharge methods. The long term goals that were in place were mainly relocation and partly training of the community on the protection of the water resources (Table 5-11 & 5-12). The analysis on the frequency of implementing awareness campaign showed that the two best frequencies that would work will be monthly or annual awareness campaigns. A further analysis of the initiatives taken by the different stakeholders such as the community, the NGOs and the GoK, showed that community was mostly interested in the initiatives that involved the issue of ground water recharge as opposed to the issue of protecting the water sources as they are not willing to relocate from the top hills which is the springs recharge zone. Studies done by John (2012) showed that for sustainable land management, community awareness creation needs to be continuous for more understanding of the facts. There is therefore a need to unite the stakeholders offering awareness campaign so as to allow the different campaign team to work in harmony with each other as opposed to each working alone and duplicating the work on the ground. This make the community to lose the meaning of the awareness and concentrate on the allowances awarded to them by each group.

6.10 Hypothesis Testing

Hypothesis testing is part of the findings of the parameters which are tested in the research to prove the assumption true of forces. In our study, the major parameters in question are the Rainfall variability, forest degradation and the spring's production. Table 5-14 which is the analysis of the hypothesis number on which states that, there is no relationship between forest degradation and springs production gives a clear indication there exists relationship between rate of deforestation and spring discharge. This test is also in line with the findings on spring's production declining tread and the declining annual rainfall production of Nuu and Mutaitho hills which bear the same characteristic. $F > F$ crit (19604.35> 4.256495) meaning that we reject the null hypothesis. The means of the three populations are not all equal but at least one of the mean is different hence there is significant relationship between spring discharges and the rate of deforestation in Nuu hills catchment. The result of the test means that for every increase in rate of deforestation it impacts negatively on the spring's production.

Table 5-16, which is an analysis of the hypothesis number two which states that there is no relationship between rainfall reliability and springs production also gives a clear indication that, $F > F$ crit (11345.86> 4.256495) meaning that we reject the null hypothesis. Therefore, we reject the null hypothesis. The means of the three populations are not all equal. At least one of the means is different hence there is significant relationship between spring discharges and rainfall variability in the Nuu hills catchment. The rejected results of hypothesis testing of relationship between rainfall variability and spring discharges gives a clear indication that, rainfall variability affect the behavior of springs discharges in that, low rainfalls reduces the springs recharges with time and also high rainfalls increases the productions of springs within the study area.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter presents the key findings, conclusion and recommendations of the study. The conclusions and recommendations are based on the results of the data analysis presented in earlier sections of the thesis. The findings presented in this chapter will enable the policy makers in the area to make more informed decisions in natural resource utilization in more sustainable way.

7.2 Key findings of the Study

One of the key objectives of the study was to provide natural resource managers with data and information to enable formulation of appropriate policies and strategies for sustainable land management in the Nuu and Mutaitho hills. From the study it has been shown that sustainable resource management can be attained by enhancing the ability of the local communities to mitigate adverse impacts of climate changes by adopting appropriate technologies that promote socioeconomic resilience. In view of the scale of environmental and livelihood problems caused by increasing deforestation in Nuu area, effective interventions are now required.

Historically, Nuu and Mutaitho hills have been both economically and politically neglected but with the political change in Kenya, there is an opportunity to protect these extensive arid and semi-arid areas through sustainable land management programmes. Land and water resources being the foundation of life in the arid and semi-arid areas, the results of the study will be critical in establishing benchmarks sustainable water resource management through protection of springs. (Duckworth, et al., 1993).

From the discussion in chapter six (6) above, the rainfall trend in the Nuu region over the period of 22 years has been showing significant variability and there is a negative trend. The reason for the high rainfall that is received in the years 1997-1998 is as a result of the southern oscillation (El-Nino) phenomena. The spring discharge over the years has been reducing drastically. There is a lag between rainfall and spring discharges.This is due to the differences in time taken for water to infiltrate in to the soil and the slow rate of ground water flow to the springs. The study found that that there is a decrease in the forest cover. The main cause of the decrease in forest cover is mainly deforestation which is caused by felling of trees for livestock grazing, farming or charcoal production as the local communities are not majorly involved in conservation of the forests. Forests are mainly used as recharge areas. The infiltration rate of water in this area is very slow allowing little water to reach the water table and ultimately slow ground water recharge which in turn feeds the springs. The local community lacks this information and do not understand the effects of clearing the recharge zones. The effects of deforestation is causing rapid generation of surface runoff due to low rate of infiltration allowing high rates of soil erosion which also increased sediments transportation in Enziu river that receives its water from the Nuu and Mutaitho hills. The river water is highly turbid thus limiting the use of water for domestic purposes. The rapid flow of the river means water is not usually available during the dry season and thus means lack of water for the local communities.

The results also showed that the youth aged between 30 and 40 years earns very little monthly income hence there is possibility that the local's income generating activity is charcoal production and tree poaching that may be detrimental to the protection of the Nuu catchment areas. The main cause of the deforestation is as a result of the people not being fully aware of the relationship that exists between the forest and the spring discharge. The study also concluded that, there was a significant relationship between spring discharge and the rate of deforestation within the Nuu region. The study also concluded that, there was no significant relationship between spring discharge and rainfall variability in the Nuu region.

7.3 Conclusions of the Study

7.3.1 Land use activities and degradation of springs

Based on the discussions and the results of this study in the respective sections, it can be concluded that there was a decrease in forest cover and increase in human agricultural activities within Nuu and Mutaitho hills catchment area. It was also concluded that the youth in the area is engaging a lot in charcoal production which is also hastening tree poaching leaving the catchment area bear. This study also concluded that, land tenure within Nuu catchment is affecting the conservation initiatives as the local communities do not own land within the catchment area and this has caused laxity of the local communities in participating in sustainable management of the catchment area. From the above findings, the study has concluded that local communities have not understood the relationship between forest cover and springs discharge leading to more vegetation cover degradation of the spring's catchment area. Thus, more capacity building needs to be done within Nuu and Mutaitho hills catchment area. Finally, the Government role of protecting gazetted areas or water towers need to be affirmed.

7.3.2 Decline in rainfall and springs discharge

From the results analysis of this study it was also noted that there is a significant relationship between spring discharge and rainfall variability within the Nuu region, thus the rainfall tread is seen to be decreasing from fast to current and the same is expected to continue unless mitigation measures are taken. Spring discharge which is also diminishing with time as seen in the earlier chapters of the thesis, is impacting negatively on community livelihood as is directly affecting the community health wise because of unforeseen lack of clean water for human consumption. Therefore we conclude that, measures need to be taken on the reasons of rainfall fluctuation as stated in 7.3.1 (issues of land cover declination) to mitigate the spring's production decline.

7.3.3 Impacts of decline in springs flow

Springs are found on the forested slopes of high mountains and hills emanating from unconfined aquifers such as those in Nuu region and are considered important sources of water for rural communities in the Nuu region. Due to the impacts of vegetation cover changes, coupled with anthropogenic causes which has caused rainfall decline within the region as evidenced by the study, reduction in the rainfall distribution marked decline in the total spring's production. The springs in Nuu Hills are drying leading to reduction of base-flow in seasonal rivers emanating from the Hills. This in turn has reduced the availability of water for both domestic and livestock uses.

From this study we therefore conclude that communities in the Nuu region are heavily dependent on springs for water supply. Although there are also found other several sources of water like earth-dams, water pans and boreholes, these water sources do not last throughout the year especially during dry period. Therefore, water shortages for domestic in Nuu region becomes a serious problem almost throughout the year. As a result, most of the local community depends entirely on relief food and water. During the dry period, local community tends to converge at the Nuu springs to scramble for the little remaining flow from the springs.

7.4 Recommendations

This study came up with a number of recommendations that are presented in the following sections. The recommendations are directed to stakeholders in water resources management (National government, County government and none governmental organizations)

7.4.1 Recommendations to County Government of Kitui (CGOK)

In order to reduce the degradation of Nuu hills catchment area, County government of Kitui should consider doing the following:-

- Intensify civic education through implementation of community awareness campaign focused on forest and water conservation.
- Formulate policies to control detrimental activities such as cultivation on steep slopes livestock and charcoal burning.
- Gazzetment of the forest in order to control access to the forest by unauthorized members of the community.

7.4.2 Recommendations to National Government

The government is urged to do the following:-

- Promote join forest management by prompting community participation in forest conservation and protection of springs.
- Create an enabling environment through policy formulation and monitoring of the levels of adherence by the respective bodies under the national government.
- Formulate and customized policies and regulations that are in line with the requirement of the environment like Forest Act, Water Act, and EMCA also the guidelines provided by the world environmental organizations.

7.4.3 Recommendations to parastatals/NGOs and government institutions

NGOs/Parastatals are also urged to take part in sustainable utilization of land resources, Organizations such as Tanathi Water Services Board, Kenya Forestry Research Institute (KEFRI), Kenya Forests Services (KFS), National Environment Management Authority (NEMA) and Water Resource Management Authority (WARMA) and other NGOs should promote community reforestation of the recharge zones by replanting trees.

- The institutions mainly GOK/Parastatals eg Tanathi WSB, Kenya Forestry Research Institute (KEFRI), Kenya Forests Services (KFS), National Environment Management Authority (NEMA) and Water Resource Management Authority (WARMA)to promote regular civic education programmes in utilization and management of land resources in the region (Nuu region).
- Key institutions Kenya Forests Services (KFS), National Environment Management Authority (NEMA) and WARMA to ensure implementation and adherence of the current policies on forest conservation or protection.
- Working in partnership with others in the public and private sectors to leverage resources and avoid duplication

7.4.4 Recommendations for further studies

Further studies are required on the improvement of data quality and availability. Thus the researcher recommends further studies in the following areas:-

- More detailed analysis and follow ups on MODIS data analysis for the region should be conducted so as to ascertain the rate of forest degradation in the region over the years.
- A detailed study of the relationship between rainfall and ground water recharge in the region needs to be undertaken so as to clearly understand the exact relationship that exist between the two parameters in the Nuu region.

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ANNEX 1: Questionnaire 1: Effects of forest degradation on spring waters for key informants

I am Rose John a student in SEKU University, am currying out a research on partial fulfillment of the requirements for the degree of MSc. Integrated water resources and watershed management in the School of Water Resources, Science and Technology. This questionnaire is for collection of information of effects of forest degradation on spring waters within Nuu and Mutaitho hills in Kitui County, Mwingi east Sub County. The information received is for academic purpose only and will be treated with confidentiality. I kindly request you to help me in active participation by responding to the following questions. Tick appropriately the answer you think fits the question.

Respondent's Name:

Respondent's position:

1. Does the local community know about effects of forest degradation on spring's water?
   YES
   NO
2. How often do you visit the community to create awareness on forest degradation and spring water production?
   a) Weekly
   b) Monthly
   c) Quarterly
   d) Yearly
3. What measures/initiatives has been taken or in place to help in reviving the springs water production.
   a) Ground water development
   b) Protection of the water sources
   c) Groundwater recharging
4. Are there any other stakeholders involved in reviving the spring's water production?
   YES
   NO

B. If yes mention

   a) NGOs

b) Community members

c) Politicians

d) GoK (Parastatals)

5. What part do you as the ministry and other stakeholders play in promoting reforestation?

   d) Public awareness campaign

   e) Incentives

   f) Trainings

   g) None

6. What techniques do you use in creating awareness on reforestation and forest conservation to mitigate water resource depletion?

   a) Recognize and applaud water conservation measures

   b) Awards to persons with ideas on rain water harvesting

   c) None

7. What problem do you face creating awareness on forest conservation?

   a) Policies

   b) Political

   c) interferences

   d) Unwillingness of the community

   e) None

8. Are there any long-term and short term goals /plans that have been set to cub the problem of spring's water production in Nuu location.

   Long-term

   a) Ground water recharge

   b) Relocation on upper hill settlement

   c) trainings

Short-term

a) Ground water recharge

b) Incentives

c) trainings

ANNEX 2: Questionnaire 2: Effects of forest degradation on spring waters for Household

I am Rose John a student in SEKU University, am currying out a research on partial fulfillment of the requirements for the degree of MSc. Integrated water resources and watershed management in the School of Water Resources, Science and Technology. This questionnaire is for collection of information of effects of forest degradation on spring waters within Nuu and Mutaitho hills in Kitui County, Mwingi east Sub County. The information received is for academic purpose only and will be treated with confidentiality. I kindly request you to help me in active participation by responding to the following questions. Tick appropriately the answer you think fits the question.

Name of the respondent: ……………………………

SECTION A:

PERSONAL INFORMATION

1. Respondent's age group:

   18-30 years

   31-40 years

   41-50 years

   50 years and above

2. How many occupants do you have in your house?
   a) 0-3
   b) 4-7
   c) Above 7
3. What level of education have you attained?
   a) Primary school

   b) Secondary school

   c) Collage

d) University

e) Others

4. What is your average monthly income?
   a) 1000-10000

   b) 10000-20000

   c) 20000-30000

   d) Above 30000

5. What is your source of income?
   a) Livestock production
   b) Farming
   c) Retail business
   d) Employment
   e) Other economic activities (selling farm produces or livestock in the market)
6. Do you own piece of land

   YES

   NO

   B. If yes which activity do you practice in your land?

   a) Farming
   b) Grazing
   c) Agro forestry
   d) Others(Mention)

Section B:

<u>EFFECTS OF FOREST DEGRADATION ON SPRING WATER PRODUCTION</u>

7. Where do you get your source of water
    a) River
    b) Spring
    c) A well
    d) Dam
    e) Others (mention)
8. How far is the nearest source of water?
    a) 0-200
    b) 201-400
    c) 401-600
    d) 601-800
    e) 801-1000
    f) Over 1km
9. Which years do you remember the spring flow was high?
    a) 1980-1985
    b) 1986-1990
    c) 1991-1995
    d) 1996-2000
    e) 2001 to date
10. What do you think made the springs flow reduce or diminish?
    a) Reforestation
    b) Encroachment by community
    c) Cultural practices
    d) Climate change
    e) Over usage of water
11. Do you know the relationship between the forest and water?
    a) Yes
    b) No

12. If yes, what effort has been done to conserve the forest for more production of water?

a) Planting more trees

b) Best farming practices

c) Northing

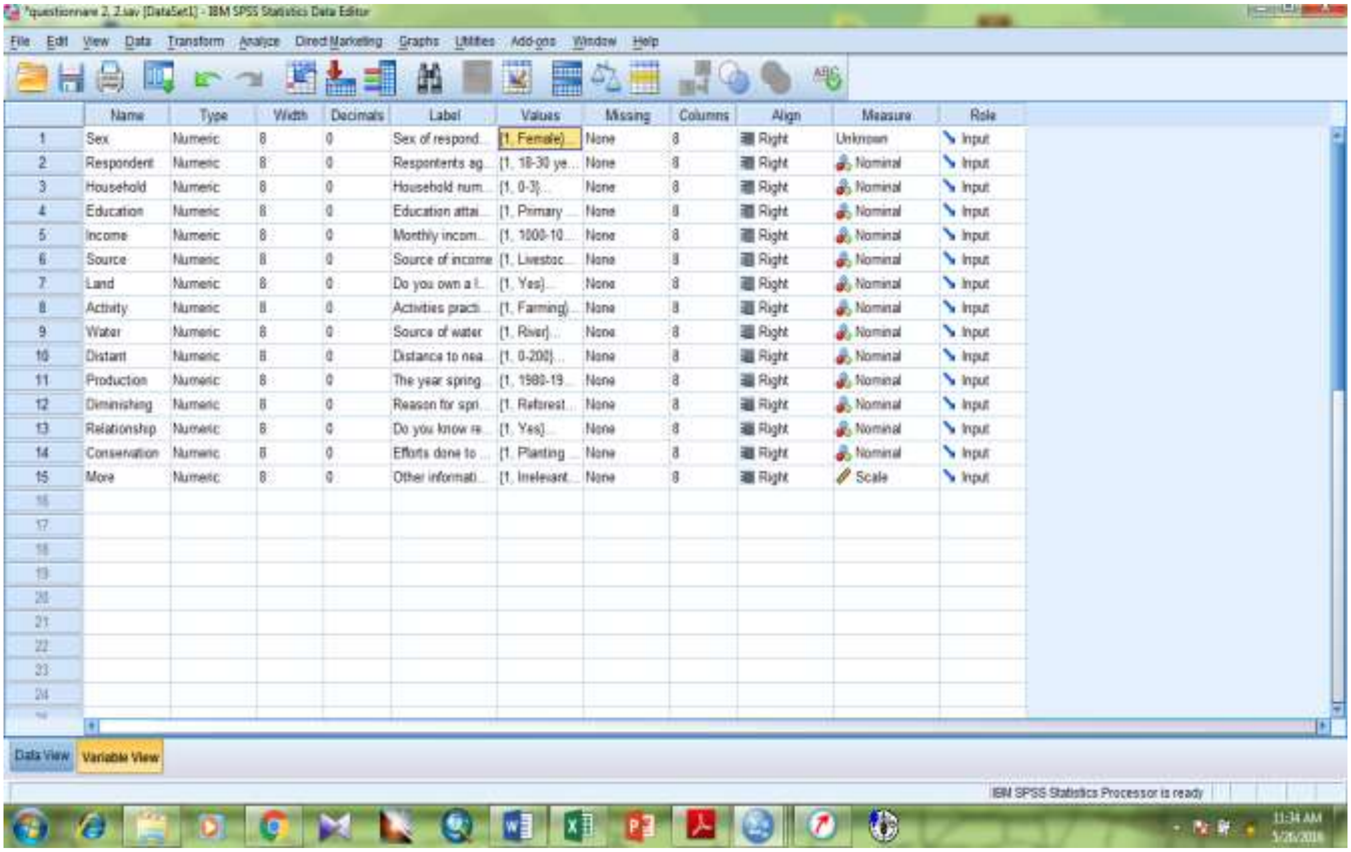
13. Any other information related to the spring's production, explain.

a) To be given in story form.

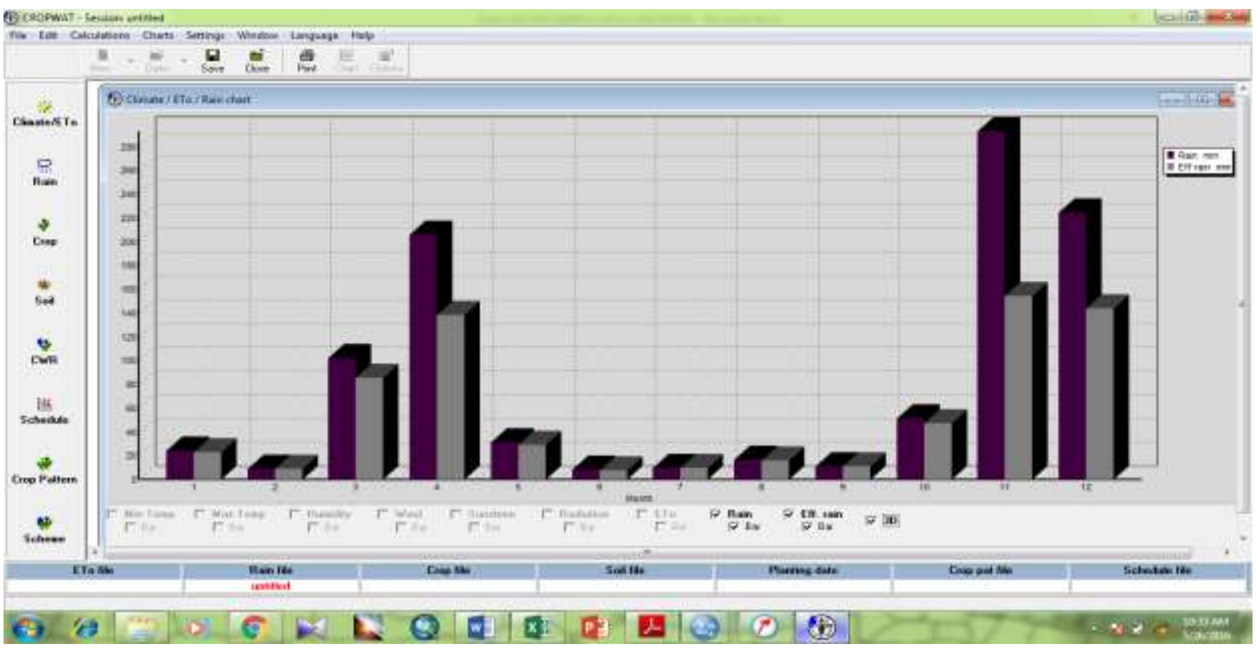
ANNEX 3: Rainfall data collected per month for Nuu yard station from 1981 to 2002 years

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual rainfall
1981	2.4	5.2	178.4	214.7	102	2.7	7.6	13.4	5.7	66.9	128.1	60.4	787.5
1982	5.7	1.8	47.9	202.8	129.6	7.1	10.4	11.9	13.2	254.9	150.1	95.8	931.2
1983	2.5	49.2	18.1	216.7	47.1	21.2	8.7	11	4.6	36.5	63.3	155.3	634.2
1984	5.3	1.2	10.7	153	11.9	1.9	12.1	5.1	10.4	181.8	376.4	91.9	861.7
1985	7.2	20.6	99.8	163.1	62	3.8	13.5	10.4	5.9	52.6	112.9	50.7	602.5
1986	3.4	1.7	62.9	239	48.8	7.8	4.4	8.9	3.7	41.8	269.2	115.2	806.8
1987	10.1	0.5	13.8	193.5	89.8	7.4	10.8	26.3	1.1	6.2	125.9	21	506.4
1988	24.1	9	102.1	206	31	8.1	9.9	16.5	11.2	51.8	292.9	224.5	987.1
1989	28.1	9.8	53.7	188.8	59.7	1.6	11.7	11.2	9.8	98.8	305.3	92.9	871.4
1990	29.4	36.6	202.3	171.5	43.5	2.7	7.3	5.8	7	116.3	246.2	196.1	1064.7
1991	17.2	2.2	56.4	222.7	64.3	3.6	23.1	16.4	4.1	34.7	142.9	145.7	733.3
1992	8.9	4.6	5.2	200.1	76	1.2	11.4	7.1	4.2	50.3	278.9	194.9	842.8
1993	109.8	25.2	24.4	78.7	23.4	8.6	7.6	6.5	2.8	72	179.7	77.9	616.6
1994	1.2	8.9	22.1	135.5	41.3	6.7	16.5	10.5	13.3	219.1	409.7	162.7	1047.5
1995	6.8	21.9	77.6	152.7	38.4	3	7.6	32.4	5.4	281.1	117.7	127.2	871.8
1996	16.5	9	121	35.3	41	9.8	13.5	11.2	3.2	10.4	280.5	11.8	563.2
1997	5.2	2	87.2	269.1	44.1	8.9	7.1	7.7	1.5	158.5	710.1	309.2	1610.6
1998	260.8	62.3	93.3	134	183.8	14.5	23.9	15.7	3	13	189.2	24.6	1018.1
1999	9.7	5.3	95.4	101.6	26.5	0.7	9.2	13	2.8	15.5	270.7	174.3	724.7
2000	5.1	2.5	22	80.1	17.8	3	7	6.7	4.6	25.5	218.1	67.2	459.6
2001	45.9	5.1	95.8	142.6	28.3	7.3	9.1	6	2.4	18.7	372.7	31.3	765.2
2002	12.9	8.7	75	35.3	41	9.8	13.5	11.2	3.2	10.4	280.5	11.8	513.3

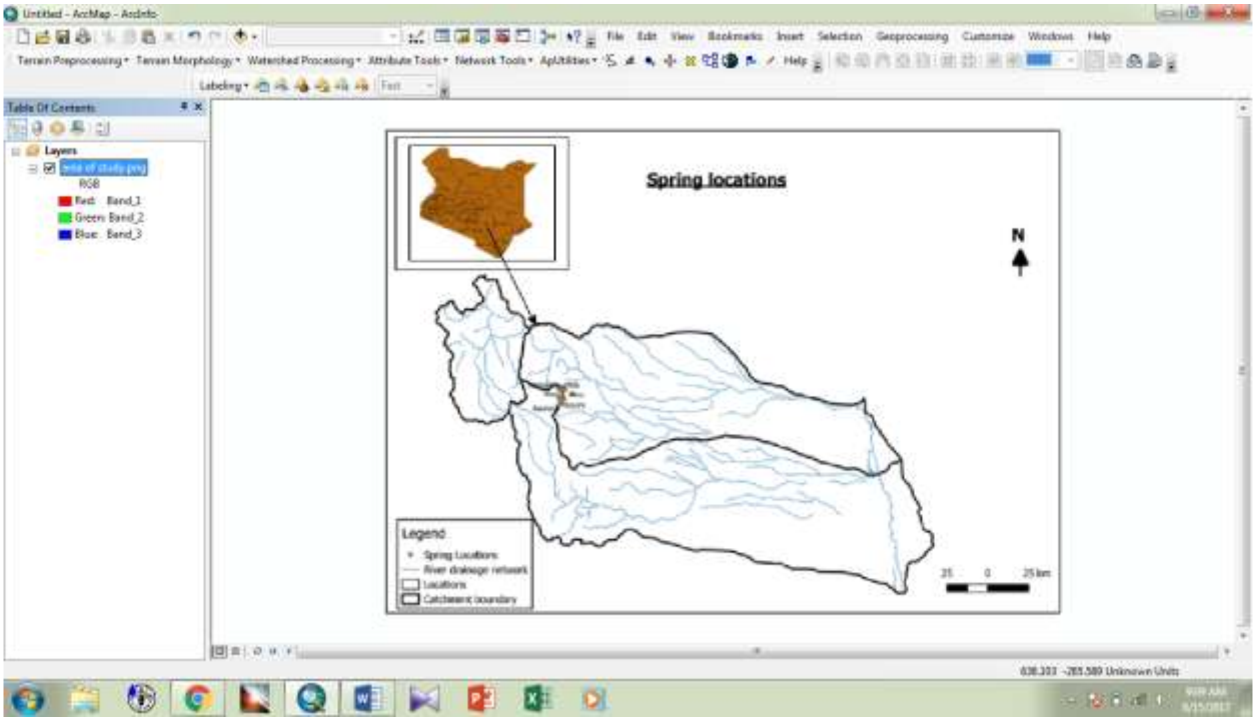
ANNEX 4: SPSS questionnaire analysis programme (SNAP SHOT)



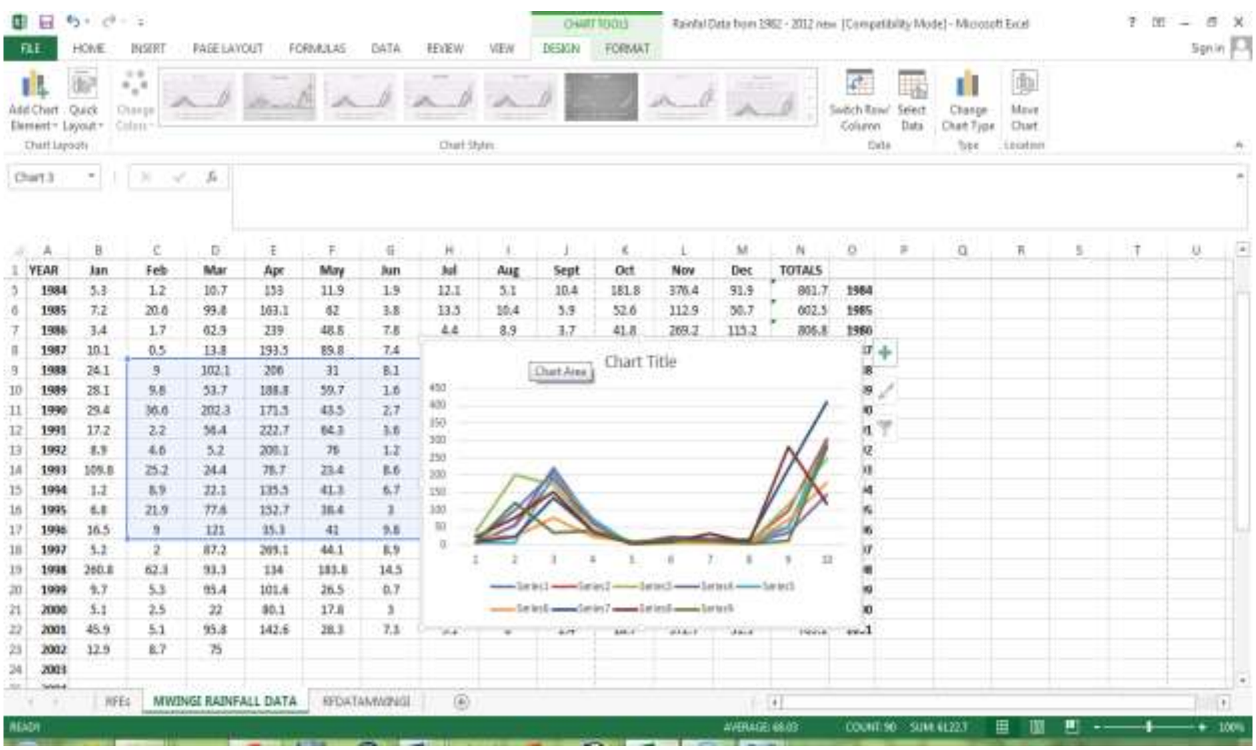
ANNEX 5: CROPWAT-session programme for rainfall analysis



ANNEX 6: GIS ARC map page extracting of catchment of the study area



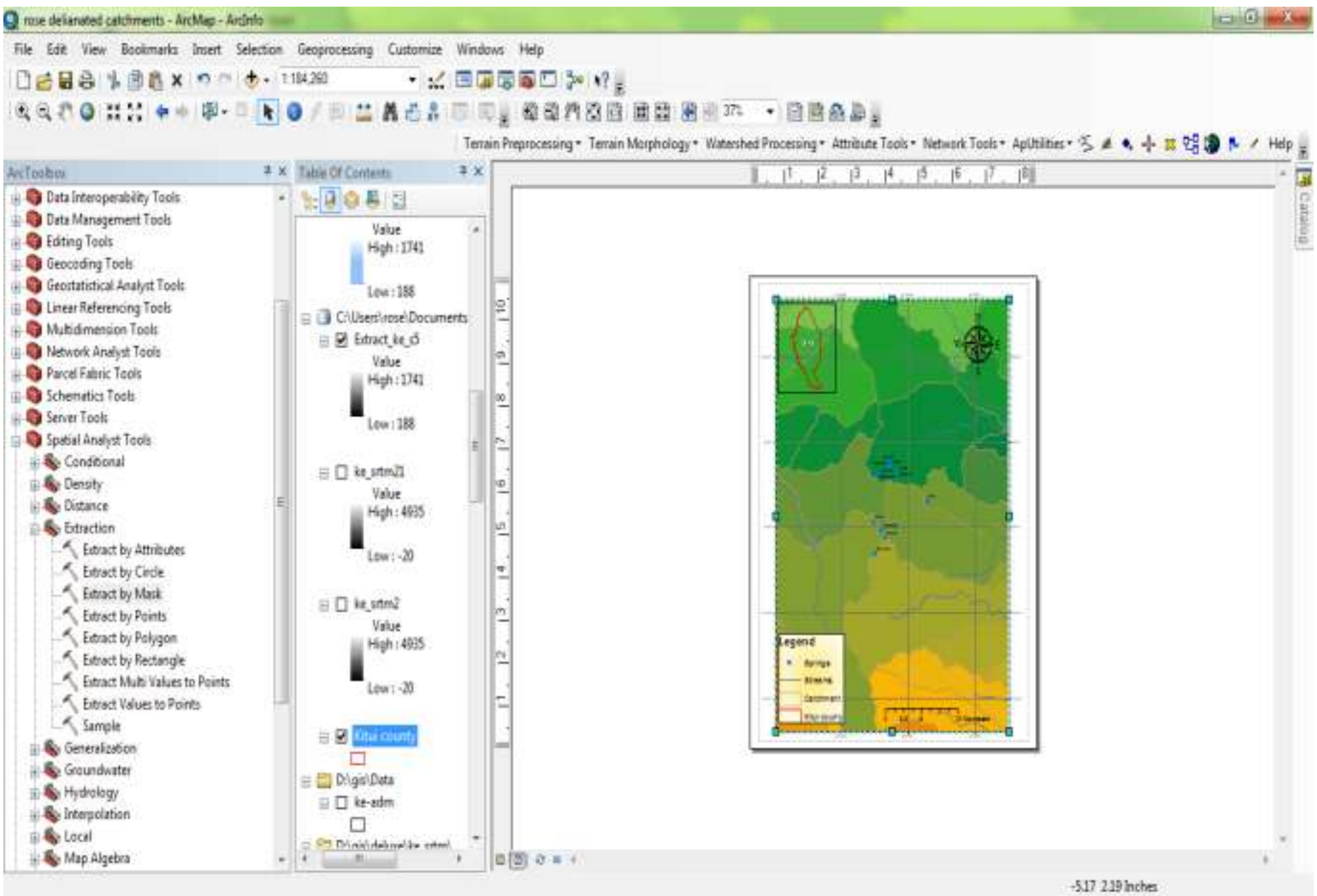
ANNEX 7: Screen snap shot of Ms. Exel used



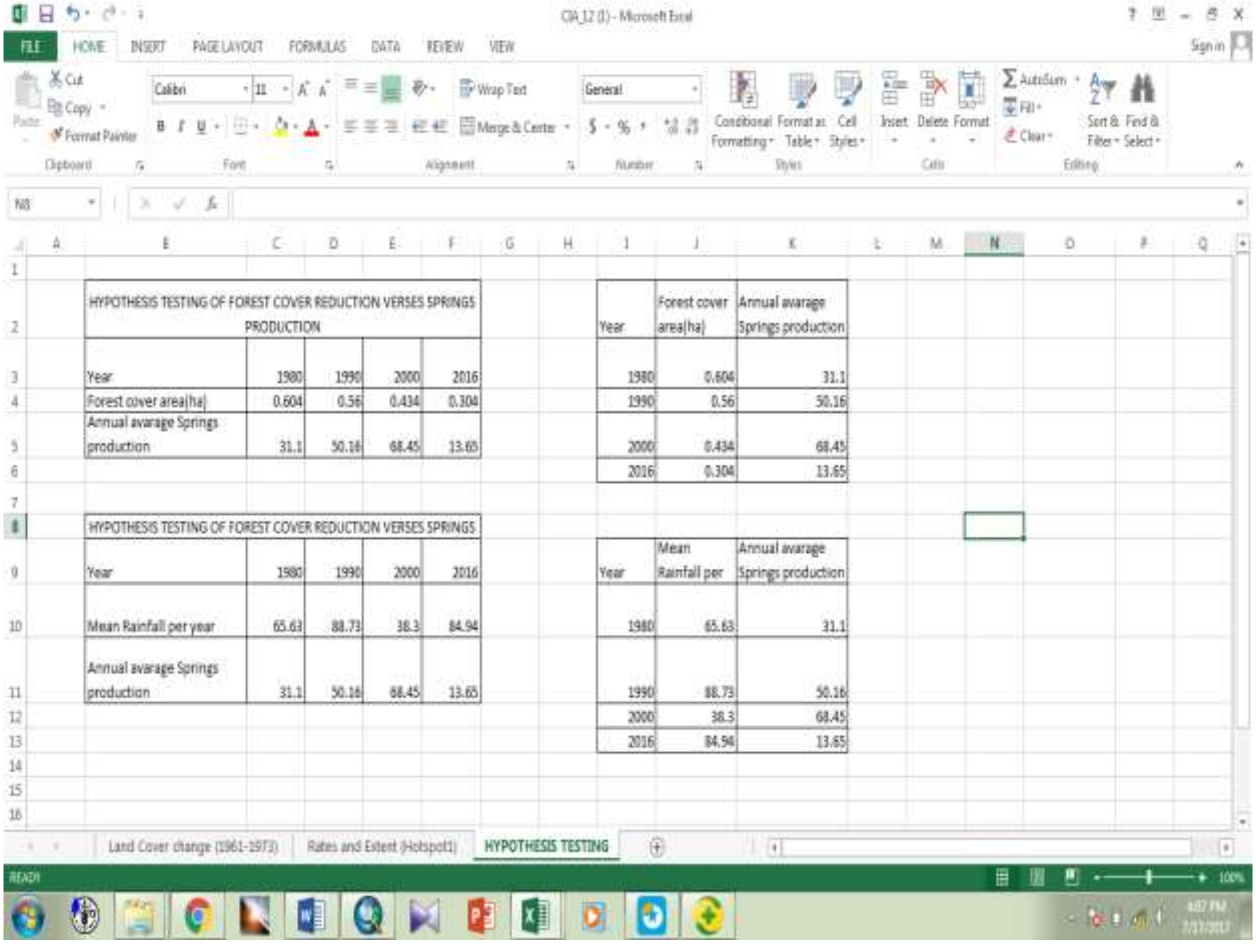
ANNEX 8: Rainfall data for Nuu yard station 2011-2015

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	TOTALS
2011	17.2	2.2	56.4	180	64.3	3.6	23.1	16.4	4.1	34.7	133	145.7	680.7
2012	10.1	0.5	13.8	193.5	89.8	7.4	10.8	26.3	1.1	6.2	125.9	21	506.4
2013	2.5	49.2	18.1	216.7	47.1	21.2	8.7	11	4.6	36.5	63.3	155.3	634.2
2014	45.9	5.1	95.8	142.6	28.3	7.3	9.1	6	2.4	18.7	372.7	31.3	765.2
2015	24.1	9	30.2	150	31	8.1	9.9	16.5	97.1	126	292.9	224.5	1019.3

ANNEX 9: GIS ARC map page extracting Land use map for Nuu region



ANNEX 10: Hypothesis testing tables in excel



HYPOTHESIS TESTING OF FOREST COVER REDUCTION VERSES SPRINGS PRODUCTION				
Year	1980	1990	2000	2016
Forest cover area(ha)	0.604	0.56	0.434	0.304
Annual avarage Springs production	31.1	50.16	68.45	13.65

Year	Forest cover area(ha)	Annual avarage Springs production
1980	0.604	31.1
1990	0.56	50.16
2000	0.434	68.45
2016	0.304	13.65

HYPOTHESIS TESTING OF FOREST COVER REDUCTION VERSES SPRINGS				
Year	1980	1990	2000	2016
Mean Rainfall per year	65.63	88.73	38.3	84.94
Annual avarage Springs production	31.1	50.16	68.45	13.65

Year	Mean Rainfall per	Annual avarage Springs production
1980	65.63	31.1
1990	88.73	50.16
2000	38.3	68.45
2016	84.94	13.65