

**LANDUSE AND LANDCOVER CHANGE ON WATERSHED FUNCTIONS IN
TUNGU-NAKA RIVER SUB-CATCHMENT IN THARAKANITHI COUNTY,
KENYA**

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DECLARATION

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DEDICATION

This thesis is dedicated to my son Shane Mwabonje, Mom Dorothy Njeri, Dad Henry Njage, my sister Mary and my loving husband Shadrack Mwabonje for their continuous prayers and encouragement. Mama you are a true blessing in my life, my heroine. Shadrack, you have been a source of inspiration and support in this entire journey. I say thank you for your unremitting prayers and moral support.

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ABBREVIATIONS AND ACRONYMS

FAO	: Food and Agriculture Organization
GPS	: Geographical Positioning System
KNBS	: Kenya National Bureau of Statistics
KEWASNET	: Kenya Water and Sanitation Civil Society Network
LC	: Land Cover
LCC	: Land Cover Change
LUC	: Land Use Change
LU	: Land Use
NACOSTI	: National Commission for science, Technology and Innovation
SPSS	: Statistical Package for Social Sciences
SWAT	: Soil and Water Assessment Tool
TUWRUA	: Tungu Water Resource Users Association
UNEP	: United Nations Environmental Programme
WOR	: Watershed Organization for Restoration
WRMA	: Water Resource Management Authority

OPERATIONAL DEFINITION OF TERMS

Affluence is the improvement in living standards resulting from technological advances.

Land use implies how human beings use the land, for example, settlement, farming, lumbering, and the establishment of institutions like industries, among others. It involves the management and the conversion of natural resources to the way suits man. It was measured in the form of figures and percentages, and thereafter, producing maps.

Land cover is the physical or natural material on the earth's surface, for example, bare ground, vegetation, impervious and water surfaces on which land use occurs, for example, forest, agriculture, water, wetlands, residential, rocks, and bare ground. It was measured in the form of figures and percentages.

Land cover change is the change in the physical or natural coverage on the ground's surface, for example, replacing forest with agriculture and clearing vegetation for settlement.

Watershed functions are the processes of water capture, storage, and release within the watershed. In this study, the researcher focused on examining the quantity of water in the river, the wetlands, erosion in the watershed, and the presence of a riparian zone, rather than investigating underground water.

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ABSTRACT

Watersheds provide a main function of maintaining ecological balance and giving the most important services, like a home for biodiversity, water provision, and agricultural yields. The Tungu-Naka sub-catchment is an important hydrological unit that maintains different socio-economic activities for the communities in the watershed. The primary objective of this research was to assess the impacts of land use and land cover change (LULCC) on watershed functions in the Tungu-Naka River sub-catchment, Tharaka Nithi County. The specific objectives were to: (1) analyze the trends in land use and land cover in the Tungu-Naka watershed from 2002 to 2018, (2) identify and evaluate the driving factors of land use and land cover change in the Tungu-Naka sub-catchment between 2002 and 2018, and (3) assess the impacts of land use and land cover change on hydrological and ecological functions of the Tungu-Naka watershed. A mixed-methods research design combining both qualitative and quantitative approaches was employed. LANDSAT TM imagery from 2002, 2006, 2012, and 2018 was obtained from the Regional Center for Mapping of Resources for Development (RCMRD) in Kasarani. These images were used to analyze LULCC over the study period and partially evaluate its impacts on the Tungu-Naka sub-catchment through supervised classification. The study targeted households residing within the Tungu-Naka watershed, as well as key informants. SPSS software was used to examine the relationship between LULCC and watershed functions, specifically employing Pearson's product-moment correlation coefficient (r). Key findings revealed significant LULCC, including the conversion of wetlands for farming, deforestation, the destruction of riparian zones, and increased settlement. Population growth and planting of eucalyptus were identified as primary drivers of LULCC. The main impacts observed included drying of wetlands and reduced river water volumes. Population growth, urbanization, and shifts in farming practices were highlighted as significant contributors to land use changes. The research identified riparian land restoration through tree planting as a common watershed conservation strategy within the sub-catchment. However, this approach has been largely unsuccessful due to tree-cutting by farmers and its limited application in the upper watershed zones. The study rejected the null hypothesis and accepted the alternative hypothesis, confirming a statistically significant relationship between LULCC and watershed functions. There is a need for regulated water abstraction in the rivers and for strengthening the capacity of the community members on the importance of protecting riparian land. From the findings, there is a need for a debate on the suitable land use activities that can be considered in the different watersheds. Consequently, there should be proper channels of communication by the community members to the relevant authorities in case of an illegal activity within the watershed.

CHAPTER ONE

INTRODUCTION

1.1 Background to study

Watersheds provide a main function of maintaining ecological balance and giving the most important services, like a home for biodiversity, water provision and agricultural yields (Rwigi, Opere, & Muthama, 2024; Dinca, Murariu, & Lupoae, 2025). The Tungu-Naka sub-catchment is an important hydrological unit that maintains different socio-economic activities. Nevertheless, in recent times, the sub-catchment has experienced a significant LULCC largely due to population and agricultural growth, deforestation, and the expansion of urban areas. The changes have a deep impact on watershed functions, including water quantity, regulation of flow and ecological stability.

The consequences of human activities on a watershed are described differently in different watersheds depending on the value of the watershed to the residents (Geleta, Haile Salassie, Simane, Assefa, & Bantider, 2023; Meierdiercks, Finewood, & Bennett, 2024). It can be physical change and contamination from the factories and built-up areas, adjustment of buffer zone and river flow, siltation and eutrophication from the farming activities, among others (Human, Solomon, Mengistou & Ababa, 2011). In general, watershed destruction must be put and accepted as a national concern since it slows the social and economic growth of the country. The weight of watershed destruction has resulted in more poverty and inadequate food production, worsening environmental conditions, and destruction of resources, especially water and riparian zones (Agwata, 2006).

A watershed comprises the stream network upstream. It involves a point on the mainstream, slopes that add water, sediments, and wood rubbles to form the network. Watershed activity in each area is influenced by a number of processes taking place in the watershed upstream, for

example, erosion. The number of sediments and the size of particles from any drainage basin will always portray the interaction between the landscape and the land use in any given region. Every land cover change in a watershed will impact the watershed and sediment volumes in the system. Consequently, there will be changes in the stream processes and form. The Tungu-Naka sub-catchment is valuable in providing water for domestic farming activities to the communities and townships within the watershed.

Irrespective of its importance, human activities have continuously disturbed catchment, hence landuse change. These consequences are not only felt by the regions that are immediately affected by the action of man, but also in regions extremely far from the immediately affected area (Ayivor & Gordon, 2012). Catchment destruction has cascading effects and other disturbances on water resources. This is because of nutrient enrichment by surface water from built-up areas and agricultural chemicals due to erosion as a result of deforestation and eutrophication (Ansah-Asare, 1995).

Molla, Gebrekidan, Mamo, and Assen (2010), in an Ethiopian study found that land use changes destroy riparian vegetation as well as a reduction in water quantity in the rivers. This was ascertained through a few studies that measured land use and cover changes in various sections of the country. The same research confirmed that LULCC factors associated with anthropogenic activities are advancing progressively. A study conducted in India revealed that land use modifications from forestry to farming activities in headwater areas normally increase sediments discharge, hence impacting the downstream channel morphology in a very complicated manner (Prokop & Sarkar, 2012; Musuva, 2010). Channel geometry can also be deeply affected by the local controls, for instance, riparian undergrowth covers the banks. And Prokop & Sarkar (2012); (Park et al., 2005). Consequently, dense vegetation intensifies roughness and binds the impacts of roots, increasing bank resistance to erosion.

Tekwa, Alhassan, and Fali (2014), ascertained that in developing countries, for instance, Ghana, conventional agrarian economies, more than 61% of the total population relies either indirectly or directly on farming activities for livelihood. In this case, therefore, utilization of land mainly depends on the interests of the inhabitants, hence determining land use.

In general, the level of LULCC has had a great impact globally in recent times. This has been linked to population growth and extreme poverty, especially in developing countries (Anderson, Hardy, Roach, & Witmer, 2001). Ayivor and Gordon (2012) , disputed with the fact that population and extreme poverty have impacted much to land use change. Instead, the two authors argued that how individuals react to economic opportunities are controlled by local and national markets and policies, hence land use change (Berget et al., 2024; Kishaija & Heil, 2025).

Research done in the Nairobi River observed that globally, open spaces in urban areas are facing threats of development needs, both in the public and private sectors (Bosco, Geoffrey, & Kariuki, 2011; Mbonaga et al., 2024). The study also found that the river channel had been diverted, causing flooding because of the destruction of riparian vegetation.

As a result, this study examined the impact of land use and land cover change on the watershed functions of the Tungu-Naka River sub-catchment. Specifically, analysed the trends in land use and land cover in the Tungu-Naka sub-catchment between year 2002 and 2018, identified and evaluated the driving factors of land use and land cover change in the Tungu-Naka sub-catchment between 2002 and 2018, assessed the impacts of land use and land cover change on hydrological and ecological functions of the Tungu-Naka watershed and evaluated existing watershed management strategies in the Tungu-Naka sub-catchment and assess their effectiveness. The study anticipated to come up with some findings and recommendations that can be helpful to the County government of Tharaka Nithi in laying down strategies of

environmental conservation; support the affected communities on sustainable watershed use and integrated watershed management; to be insightful to the institutions dealing with water governance and accountability and the central government in achieving the Sustainable Development Goals (goal 16 on environmental conservation).

1.2 Statement of the problem

The influence of Land Use and Land Cover Change (LULCC) on watershed functions is globally recognized as a critical environmental concern. LULCC holds the potential to interrupt water quality, disrupt crucial hydrological processes, and diminish the overall adaptability of affected ecosystems.

This persistent threat is manifested within the Tungu-Naka river sub-catchment, an area that maintains a vital role for its residing communities (G.O.K, 2017). The region has undergone rapid demographic changes, evidenced by a significant population increase from 52,598 in 1999 to 142,000 in 2019 (KNBS, 2019), which has resulted to urbanization and leading to changes in land use. Key drivers of this change include the expansion of Chuka town and the establishment of Chuka University, leading to the abrupt conversion of natural spaces into built-up and agricultural areas. Furthermore, large-scale deforestation as a result of increasing local demand for farmland, new settlements, firewood, and charcoal.

These changes in LULC patterns interfere with the natural hydrology of the Tungu-Naka area. The combination of reduced natural cover and high demand for domestic, industrial, and irrigation water has led to increased water abstraction. This process has resulted in a documented reduction in the overall water quantity available (TWRUA, 2018). The hydrological activities of the sub-catchment are further affected by the conversion of land into impervious surfaces, which poses a threat to both forest and water resources by likely causing a low water infiltration rate. Consequently, these changes result in an increased surface runoff,

which contributes to accelerated rates of soil erosion and sedimentation, thereby increasing water pollution, particularly from farming along the riparian land.

Additionally, despite the establishment of the TUWRUA in the region that was meant to enhance the regeneration of the watershed through community engagement, and despite the significance of the sub-catchment to the communities it serves, the watershed remains under threat. The escalating threats posed by intensified LULCC processes, including documented reduction in water quantity (TWRUA, 2018) and increased erosion, underscore the necessity for specific data. There is a fundamental lack of comprehensive studies documenting the key effects of Land Use and Land Cover Change (LULCC) on watershed functions within the Tungu-Naka river sub-catchment.

1.3 Research objectives

1.3.1 Overall objective

The study aimed at assessing the influence of land use and land cover change on watershed functions in Tungu-Naka River sub-catchment in Tharaka Nithi County.

1.3.2 Specific objectives

- i. To analyse the trends in land use and land cover in the Tungu-Naka sub-catchment between year 2002 and 2018.
- ii. To identify and evaluate the driving factors of land use and land cover change in the Tungu-Naka sub-catchment between 2002 and 2018.
- iii. To assess the impacts of land use and land cover change on hydrological and ecological functions of the Tungu-Naka watershed.
- iv. To evaluate existing watershed management strategies in the Tungu-Naka sub-catchment and assess their effectiveness.

1.4 Research questions

- i. What have been the land use and land cover trends in the Tungu-Naka watershed between year 2002 and 2018?
- ii. What are the key factors that have driven land use and land cover change in the Tungu-Naka watershed between years 2002 to 2018?
- iii. What are the effects of land use and cover change on the hydrological and ecological functions of the Tungu-Naka sub-catchment?
- iv. What watershed management strategies currently exist in the Tungu-Naka sub-catchment, and how effective are they in addressing the impacts of land use and land cover change?

1.5 Research Hypothesis

There is no statistically significant relationship between land use, land cover changes, and watershed functions in the Tungu-Naka River sub-catchment.

1.6 Justification and significance of the study

Tungu-Naka sub-catchment was selected for the study because it was among the pilot sub-catchments picked by WRMA for rehabilitation, and this led to the establishment of WRUA in 2006. Minimal research had been conducted in the Tungu-Naka sub catchment on the influence of LU and LCC on the watershed functions, especially after the establishment of TUWRUA. A study was done in the Mutonga watershed to evaluate the impacts of LU and LCC on the hydrology of the watershed, which is closer to the sub-catchment under study. However, the former study was purely quantitative while the current study applied a mixed-methods research design. Moreover, the current study did not research underground water, which was the main focus area of the former study. Consequently, temporal consideration was taken into account, whereby there is a gap of nine years from the time the former study was conducted in the

Mutonga watershed. Even with the establishment of TUWRUA, the sub-catchment is still degraded, with a reduction in the water quantity caused by over-abstraction of TWRUA (2018), as well as riparian land degradation. This prompted the researcher to conduct a study in the Tungu-Naka sub-catchment to assess the impacts of land use and land cover change (LULCC) on watershed functions in the Tungu-Naka sub-catchment in Tharaka Nithi County. The research aimed at generating evidence that can inform practical environmental conservation strategies and help the affected communities by providing possible recommendations to implement effective integrated watershed management and sustainable water use, enhancing the achievement of vision 2030 and Sustainable Development Goals especially goal number (15) on environmental conservation as well as goal number six (6) on achieving clean water and sanitation for all. Evidence about land use and land cover change is essential for the national and county governments in planning to control the risks of sudden and uncontrolled growth, the declining state of the environment, reduction in productive farming land, degradation of the watershed and swamps, as well as destruction of habitat for aquatic animals. Moreover, the study provided land use data that can be important in assessing the environmental activities and their effects on maintaining a sustainable watershed. The findings on why and how land use is changing can be used in formulating and implementing land management policies and practices.

1.7 Scope of the study

The study examined the influence of land use and land cover changes on the watershed functions within the Tungu-Naka River sub-catchment in Tharaka Nithi County. The study determined land use and land cover trends in the Tungu-Naka watershed between 2002 and 2018, evaluated driving factors of LULCC within the area of study, assessed the impacts of land use and land cover change on hydrological and ecological functions of the Tungu-Naka watershed and evaluated existing watershed management strategies in the Tungu-Naka sub-

catchment and their effectiveness. The study did not cover water quality in the sub-catchment as much as it could also be an impact of LULCC and focused only on surface water and not underground water. Geographically, the study was conducted in Tungu-Naka sub-catchment, situated in upper Mount Kenya region in Tharaka Nithi County.

1.8 Limitation of the study

The limitations anticipated during the study included the inability to cover the entire sub-catchment within the specified time, due to its vastness. To curb this, the researcher apportioned extra time for the study to ensure that enough area was covered. Consequently, secondary documents provided by TWRUA and WRMA were analyzed in addition to the primary data, for triangulation purposes. Furthermore, some respondents were reluctant to giving some information for fear of legal action, especially people who abstracted a lot of water from Tungu-Naka Rivers. The researcher assured the respondents that the information collected would be used solely for academic purposes and emphasized that their confidentiality would be upheld regarding the details provided.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.0 Introduction

This chapter will examine various articles related to the objectives being studied. The first review will be on the trend of LULCC in the sub-catchment under study, factors leading to LULCC in a watershed, impacts of LULCC on watershed functions and existing strategies for integrated watershed management and their effectiveness.

2.1 Watershed LULCC trend

LULC keeps on changing globally, but the change is influenced by different factors ranging from one watershed to another. According to Lowder, Skoet, and Singh, (2014), the annual percentage of world's tropical forest lost is 0.9 %. The workers reports that this is the trend globally, in all types of forests and for different reasons. Kenya had lost an average of 12,050 ha a total of 6.5% of the total forest cover between 1990 and 2010, (Lowder et al., 2014). Furthermore, a study conducted in Chitwan District of Nepal to analyze the growth of agricultural sector found that agricultural land cover has increased with over 30% in the last three decades, mostly due to population growth and demand for food supply (Jha, Singh, Poudel, Shingh, Tiwari, & Shrestha, 2021).

Consequently, Rawat and Kumar (2015), conducted research in India on the changes in LU/LC through GIS method in Ramnagar town area. The research found that between year 1990 to 2010, the built-up region grew by 8.88%, vegetation declined by 9.41%, agricultural land reduced by 0.65% and water body declined by 2.76 %. Through remote sensing, the study

observed that the town was expanding at a very high rate hence becoming a threat to the water bodies in the region. On the other hand, a study conducted to monitor LULCC using GIS and remote sensing in a diverse area in India at the same time period found vegetation and built-up area had expanded by 3.51% and 3.55% respectively, while on the other hand, agriculture, barren land and water body decreased by 1.52%, 5.46% and 0.08% respectively. This is contrary to the former study whereby vegetation cover was found to decrease.

Moreover, research through mapping and analysis of LU/LCC using GIS and RS in Simly watershed in Pakistan found that there has been a huge decline of 38.2% and 74.3 in vegetation and water cover, respectively (Butt, Shabbir, Ahmad and Aziz, 2015). This was found to cause a threat to the watershed under study; hence, an urgent response is required to protect the watershed.

In a study by Verbist, Eka, and Putra (2005) on the effects of land use change, it was found that forest cover in the area had dropped substantially, from 60% in 1970 to just 12% by 2000. The biggest land that had been occupied with forest before was replaced with farming, especially coffee, while other areas were found to have been swapped with settlement and infrastructure, specifically roads. The area covered with coffee in the area was found to have expanded from 10% to 70% during the same period, though they did not come up with a way to curb the problem brought about by LULCC.

Furthermore, Wu (2008), carried out a study in the USA on land use changes from the year 1982 to 2008. From the research, it was found that there has been an advanced change in land cover and use in the area whereby the section covered with cropland, pasture, and rangeland was reported to have reduced by 76 million acres in the lower states, and the total area under development increased by 48%. The former study gave the general trend of land use without specifying the trend-specific land use categories.

Consequently, Musuva (2010) in the south-western US study found that the region covered by rangeland was depleting drastically, due to the expansion of farming and settlement in the region. The same research reviewed that built-up areas and roads were also expanding every year. The study applied only GIS and the trend was for a period of eight years while the current study applied satellite images covering the trends for 19 years. Moreover, interview schedules were also used in the current study for triangulation purposes.

In addition to the above studies, Alemu, Garede, Eshetu, and Kassa (2015), in their study on land use and cover changes in the lower parts of Northern Ethiopia, reviewed that there was severe pressure on the area covered by woodlands since it was decreasing rapidly. Out of the places selected to carry out research, it was noted that farming land had declined at an average of 2322.9 and bare land 726.6 hectares per year between the year 1985 to year 2010. Moreover, the section covered with woodland was found reduced at a rate of 2833.8 hectares annually and 2057.9 hectares per year was found to have been converted to farming. The study did not look at the impacts of LUC on the watershed. The study was too general since it did not look at the change in different land use. Some could have gone through greater change than others.

Furthermore, a study conducted in the Sondu River basin in Kenya on the influence of deforestation on surface water yields, forest cover was found to have declined by 18.2% and a subsequent advancement in land under agriculture had increased by 18.2% in the period between 1973 and 2010 (Rwigi et al.,2024).

2.2 Factors leading to LULCC in a watershed

Land use change results from several interrelating factors emanating from distinct stages of organization in human environmental systems. The numerous driving forces of land use change differ in space and temporal, depending on certain environmental conditions of man, and can

be quick or progressive variables (Lambin, Geist and Lepers, 2003). The study, however, did not mention these driving forces that result in spatial and temporal change.

Consequently, China's study revealed that rapid economic development, increase in population, and urbanization have accelerated land use changes, hence stressing the shortages of water resources (YanYun Nian, Li, Zhou, & Hu, 2014). These findings are similar to a study conducted to assess land use and land cover change in Subarnarekha watershed of Ranchi stretch in Jharkhand in (Kadave & Kumari, 2023). The study concluded that land use change is attributed to both natural and anthropogenic activities. This can be understood by learning the mode of land use in the past, present, and future (Lambin et al., 2003). Hogan & Luzi (2010), argues that among the contributors to land use change in a watershed is the raised demand for public water.

According to a study conducted in Nigeria, continuous unrestrained human exploitation and dredging in a watershed pose risks to the watershed (Iro, 2015). Some of the LU activities found in the area included enormous and uncontrolled deforestation, uncontrolled sand mining, an increase in the constructed areas, hence an upward surge in waste disposal by man in the rivers, which includes both solid and organic. The research was conducted only at the confluence of Otamiri and Nworie Rivers, while the current study will cover the entire Tungu-Naka watershed. Furthermore, the research found that the communities living in the watershed have caused its degradation as they settle near the river to access water for domestic purposes, the suitable land terrain, and the cool breeze from the river. Bosco et al., (2011) also conducted research in the Nairobi River basin on the consequences of land use change on the watershed. The results found that an increase in urban inhabitants, private and public needs for development have contributed much to land use changes. LC in Tungu watershed has changed

because of various factors like population growth, urbanization, changes in the source of livelihood for the community, climate change and technology upgrade.

Additionally, Ghana's study found that the driving forces behind land use change are shaped by the characteristics of the rural economy and the demands of local livelihoods (Ayivor & Gordon, 2012). The surge in demand for food, fuel, and raw materials led to local and global demands for land use (Brown, Hammill, & McLeman, 2007). There could be a sustainable way of utilizing these resources within the watersheds. The current study examined the existing strategies for management of the sub-catchment under study.

Krhoda and Kwambuka (2016), conversely, investigated the impact of land use changes on river flow, channel erosion, and river morphology in the Ngong River. The results revealed that population and economic expansion lead to the expansion of towns spatially. However, the study only focused on the river geomorphology. In many instances, as the expansion takes place, environmental disasters like flooding, soil erosion, riverbank erosion, shrinking of streams, water pollution and sediment load deposition, and landslides also set in.

The research also noticed that urbanization has caused land use change from forest and grasslands to farming, built-up areas, and paved areas. Gonzales-Inca (2009) found that due to the drop and change in undergrowth cover, the rate of infiltration is lower in the farmland as compared to forested land, hence an upsurge in the rate of surface runoff in the farming land. This study disagrees with Krhoda and Kwambuka (2016), who asserts that population expansion and the rise in constructed areas as the main causes of watershed degradation, especially the surface run off.

According to Makalle, Obando, and Bamutaze (2008) The land use activities practiced in a watershed are influenced directly by the changes taking place in that watershed. LULC change has been taking place since the evolution period, and it is still taking place.

2.3. Impacts of LULCC on watershed functions

YanYun Nian, Li, Zhou, and Hu (2014), utilized the SWAT model to assess the impact of land use changes and land cover alterations on watersheds in China. Their findings indicated that these changes have led to a reduction in groundwater recharge and an increase in surface runoff. These adjustments were found to have a negative influence on ecological system of the river, as well as the hydrological cycle. Using the same model to quantify the impacts of LULCC on sediments yield in the Fincha watershed in Ethiopia, it was found that the escalated level of sedimentation from surface run off, affected river downstream by reducing the river storage capacity (Regasa & Nones, 2023). Similarly, a study done Heihe River basin in China on the impressions of land use activities on water resources, found that over abstraction of surface water and over extraction of groundwater impacted destructively on the natural environments especially on water resources (YanYun Nian et al., 2014). As a result of this, disputes developed between the villages living on upper side of the basin and the lower side of the basin. Additionally, the same study revealed that both spatial and temporal land use activities are the main contributors to change in the hydrological cycle globally, (YanYun Nian et al., 2014). Third, land use activities result to changed water demands from practices such as irrigation and expansion of urban sector, changes in the supply of water originating from meddling on hydrological procedures of infiltration, surface runoff and underground water recharge. Furthermore, from the same study, it emerged that land use activities like farming and suburban development destroy water quality due to surface runoff. However, the findings and recommendations are silent on the causes of the mentioned land use change.

Hogan & Luzi (2010), who conducted a study in North California on the impacts of watershed land use activities on stream low flows, found that conversion of natural vegetation to farming and built-up areas can abruptly inhibit evapotranspiration, and also soil permeability due to

compaction of soil. However, the study did not look at the extent of these changes but instead generalized the changes without classifying which natural vegetation has been affected \most by these changes and to what extent.

Consequently, research done in British Columbia revealed that the greatest quantity of sediments deposited in the Quesnel River basin is as a result of intensified farming activities (Smith & Owens, 2010). The study concluded that the identified environmental hitches were aggravated by the conversion of forest to agriculture and other advanced activities, such as the construction of roads and other infrastructural facilities and settlements that resulting in erosion and huge quantities of sediments being carried downstream.

Iro (2015) study on the land use activities at the convergence of Otamiri and Nworie in Nigeria revealed that riparian flora had been heavily encroached by human activities within the watershed. According to the study, about 30% of the region had been built up due to urbanization and the flora was found to have declined to about 27%. Moreover, eutrophication was found to have dominated the part of the confluence, hence rivers experiencing challenges in flow because of human waste, which was deposited in the rivers. Continuous and uncontrolled deforestation, expansion of the built-up areas, and uncontrolled waste disposal in the rivers were found to have influenced soil erosion, particularly the topsoil and eroded materials being deposited into the watershed (Rwigi et al., 2024; Dinca et al., 2025). As much as the research discussed the impacts of LUC, it did not explore if there are existing strategies for watershed conservation, and also, the study was only conducted at the confluence of the two rivers. According to, Getachew, (2014); Paper, Getachew and Melesse, (2013), land use change has an endless global effect on the watershed, especially a decline in the quality and quantity of water.

Research done in Ghana found that population upsurge and development tension have led to the destruction of riparian vegetation. In addition, the study revealed that due to excessive

agricultural practices, especially irrigation, the water level in rivers has gone down due to abstraction (Ayivor & Gordon, 2012). However, the study provides little quantitative data to illustrate the extent of riparian vegetation destruction or to classify the vegetation based on the degree of change. Furthermore, it does not address whether mitigation measures exist within the watershed. Nevertheless, LULCC in a watershed because of climate change changes its suitability for different activities, especially agriculture, hence affecting watershed hydrology and biodiversity health (Abuhay, Gashaw & Tsegaye, 2023).

Furthermore a research done in the River Kolubara basin revealed that socio-economic changes have led to morphological changes in the area and also deepened bank erosion and sediment deposition within the basin (Hogan & Luzi, 2010). The study did not investigate the causes of the impacts discussed, but the current study will consider. LULC change in each watershed impacts differently to the watershed.

Research done in the Nairobi River revealed that urban extension is concentrated on watershed zones of middle elevation areas, causing degradation of the water quality. This is mostly through the discharge of soluble contaminants and poor storm management Bosco et al., (2011). Deforestation also accelerates the geomorphic processes leading to raise in sediment yield, quicker degradation of the channel, and mass wasting (Bosco et al., 2011). The study impacts identified were mostly in urban watersheds, hence need for a study on the impacts of LULCC in a rural watershed. In general, the impacts of LUC on watersheds is brought out in the hydrological processes together with demand and supply relationship of watershed resources (Huang & Lo, 2015).

To support the discussion on the impacts of LULCC on watershed functions, in rural areas, communities that depend on the watershed resources for livelihood are mainly affected by

LULCC on the dependent watershed. This is not unique to any watershed but globally (Cheng, Zhang, Shi & Kung, 2022).

2.4. Existing strategies for integrated watershed management and their effectiveness.

The rising demand for land has caused frequent alterations in land use, but the question is how these needs can be met or achieved without compromising human and environmental sustainability. In dry lands, there can be initiation of programs that build community adaptability through watershed restoration, like the case of WOR in India, (Hale, Wollheim, Smith, Asbjornsen, Brito, Broders, Grandy, & Rowe, 2014). There should be land use planning whereby a regular assessment of land and water potential alternatives, land use, economic, and social conditions of a given location should be done (Mbonaga, 2024). This will help in coming up with old uses and practices that best meet the demands of the community, while ensuring sustainability (Cihlar & Jansen, 2001). Consequently, there should be sustainable land management methods to ensure a balance between watershed conservation needs and modern developments within the watersheds (Cheng et., 2022).

Elbag (2006), in a study conducted in the USA on the impact of neighboring land uses on surface water quality, recommended that watershed management and conservation efforts should focus on generating evidence on the types of land uses that contribute most significantly to surface water pollution. Moreover, the study recommended that the essential water quality parameters to be applied in safeguarding surface water pollution. This can only be attained through the assessment of the effects of pollution within the watershed using watershed monitoring and surveys on the land use in the watershed. The measures given were only related to water quality.

Huang and Lo (2015), proposed a need for regulation of policies related to land use, and also improved the plans related to land use change through the use of satellite imagery in order to stop uncontrolled and unsupervised developments within the watershed. There should be capacity building for communities within the sub-catchment on the impacts of their activities on the watershed functions, and how they can continue benefiting sustainably (Lenton & Muller, 2012). Moreover, there should be a law/ policy set to regulate the volume of water that can be pumped from the rivers for irrigation.

A study done in the Ngong River found that to protect the river channel from erosion, extensive conservation measures should be put into place to protect the forest from increased demand for land settlement and urbanization (Krhoda & Kwambuka, 2016). This assents to the recommendation given in a study conducted in the Mutonga River watershed that there is a need to plant more trees and involve the community in management and conservation matters (Njoka, 2012). The current study examined the existing management and conservation strategies for the sub-catchment under investigation, as well as any collaborative partnerships with community members, if applicable, and their effectiveness.

Furthermore, a study conducted in the Bwathanaro watershed in Meru North on the development of a participatory watershed plan commended that there should be an integrated approach to handle the challenges facing the named watershed (Agwata, 2006). This is achieved through capacity building, enabling community members of the Bwathanaro watershed to own the watershed, in terms of resolving conflicts related to water, managing the watershed, managing the water abstracted for irrigation, and even generating sustainable income from the watershed. From the same study, it was recommended that Bwathanaro watershed stakeholders should unite all the groups, such as women groups, schools, faith-based organizations, and community-based organizations within the watershed. This will thus promote communal ownership of the watershed, hence appropriate management and

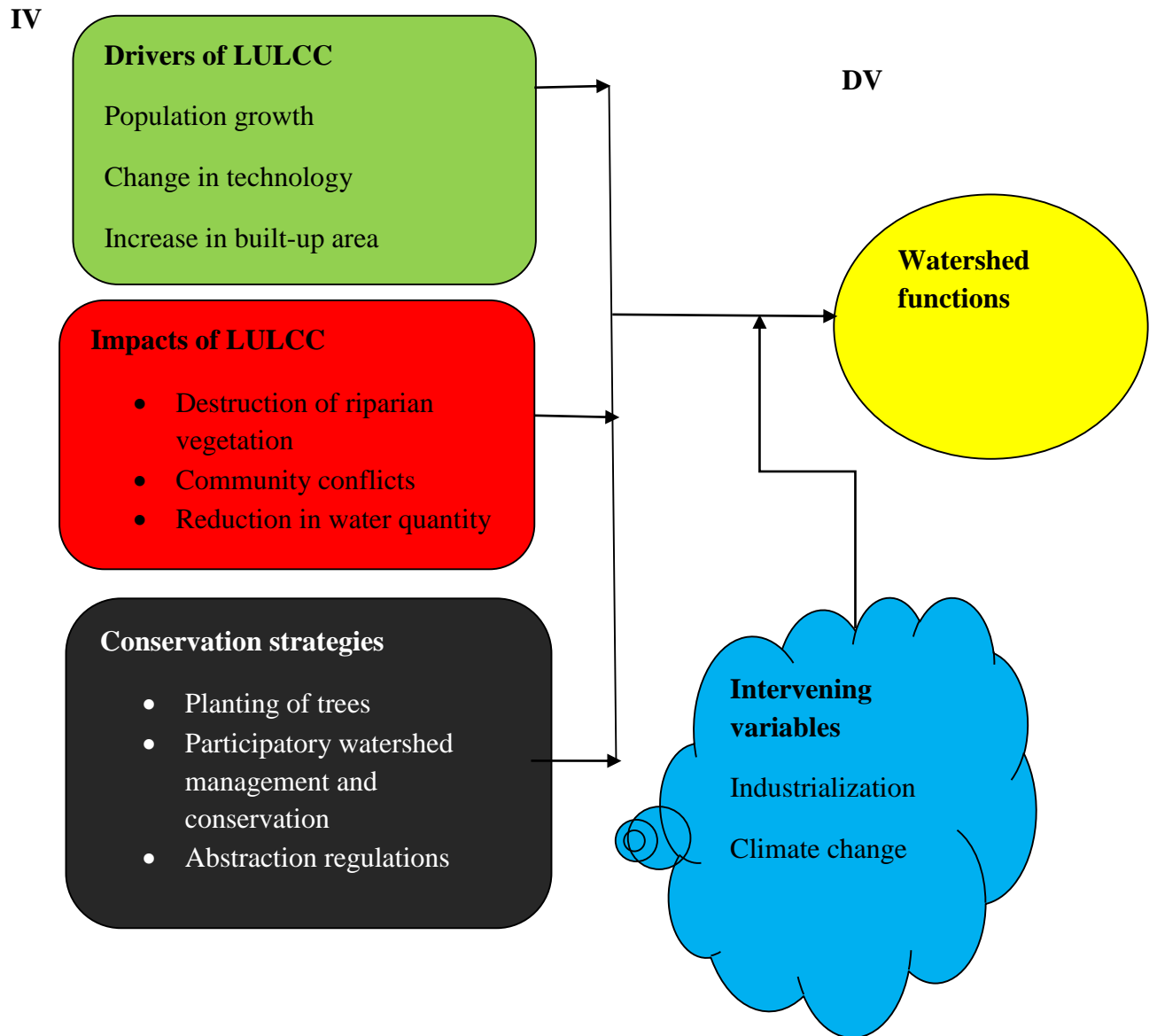
conservation measures. The former study was only on the development of a participatory watershed plan, while the current study will investigate the overall influence of LULCC on watershed functions, evaluate existing strategies, and embed them for integrated watershed management.

Contrary to Bwathanaro's study, research conducted in Ngaciuma-Kinyaritha sub-catchment in Meru County found that Community Water Management Systems (CWMSs) operating in the sub-catchment were doing so well in water resource management and farming water development, and ensuring water supply sustainability, hence scoring 62% and 50% respectively (Mathenge, Luwesi, Shisanya, Mahiri, Akombo, & Mutiso, 2014). On the other hand, the study found that in terms of achieving economic development, the CWMSs were doing poorly, hence scoring 36% and there was no efficiency and effectiveness in collaboration between WRMA, WRUA/CWMSs, and other Water Service Providers (WSPs). The study did not incorporate WRMA as part of the respondents, yet it plays the key role in watershed management and conservation, but instead used farmers, CWMSs, and WSPs.

Little has been done in the area under study, especially the Tungu-Naka sub-catchment, whereby the only study done in the region was done in the Mutonga watershed nine years ago. Moreover, the majority of studies were conducted in larger watersheds, like the one done in Mutonga (Njoka, 2012). Another study was also done in the Bwathanaro watershed in Meru North, with different climatic conditions from those of the sub-catchment under study (Agwata, 2006). Consequently, from the work done by other scholars, little has been done on the impacts of LULCC and participatory watershed management and conservation strategies, if any. The majority of studies predominantly use remote sensing (RS) and Geographic Information Systems (GIS) as their primary data collection methods. However, this study emphasizes the significance of a community participatory approach.

2.5. Conceptual framework

A merger of various proximate and underlying driving forces can establish LULCC. Proximate causes refer to human-caused activities at a simple level arising from land use that is intentional, hence impacting land cover directly, like the growth of farming that results in its extension and expansion of the built-up areas. Underlying causes are the key social factors that are global in terms of scale, for example, population change that overpowers the proximate causes and can affect LULCC either directly or indirectly. Underlying causes that can be linked to LULCC change are population change, economy and technological growth, the emergence of institutions, policy, and cultural change. Therefore, the two can be referred to as regional forces, which when they are adjusted in one region they result to change in other regions (Ayivor & Gordon, 2012). The intervening variables in this instance are industrialization and climate change, which, if the proximate and underlying factors are well contained, are not an issue. The study was anchored on the I=PAT theoretical framework, whereby I stands for the Influences responsible for the LULCC, P stands for the population, A stands for Affluence, and T is the change in Technology (Ehrlich & Holdren, 1971).



Source: *Author, 2018*

Figure 2.1. A conceptual framework on how changes in land use and land cover impact the functions of watersheds.

Table 2.1: Summary of literature review and identified knowledge gaps

Author & Year	Methods	Summary of the findings	Knowledge gap
Rawat & Kumar (2015)	GIS and Remote sensing	Built-up area expanded while the region under vegetation, agriculture and water bodies decreased.	No clear connection between these changes in LU and LC and the watershed.
Iro (2015)	Descriptive statistics	Uncontrolled human exploitation and dredging in a watershed possess threats to the watershed.	No mitigation measures provided on the negative effects of LU/LCC Only concentrated with human threat at the confluence and not the entire watershed
YanYun Nian et al. (2014)	GIS Inferential statistics	Over abstraction of surface water and over extraction of ground water impacted adversely on the natural environments. Community conflicts between people living in the higher and the lower side of the watershed.	No clear understanding of the causes of this human behavior. No integrated working plan between the community and the institution responsible for watershed management.
WRMA (2006)	Descriptive	No community participation on development of watershed management plan.	No clear implication of community activities to the watershed.
Njoka (2012)	GIS Descriptive	Human activities led to reduction in water quantity. Community involvement in watershed management.	No clear information on the effectiveness of community involvement in watershed management.

Source: Literature review

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This section covers the study's area of focus, research design, target population, sampling methods, research instruments, pilot study, validity and reliability, data collection and generation techniques, data analysis procedures, and the ethical considerations adhered to throughout the study. A mixed-methods research design was utilized, combining both qualitative and quantitative data collection approaches.

3.2 Study Area

3.2.1 Location

Tungu-Naka sub-catchment is located in the upper Mount Kenya region, upper Tana basin, passing through Tharaka Nithi and Meru Counties in Kenya. Figure 1 shows a map of the Tungu-Naka sub-catchment delineated from the map of Kenya. The watershed lies between latitude $00^{\circ} 07'$ and $00^{\circ} 26'$ South and longitudes $37^{\circ} 19'$ and $37^{\circ} 46'$ East. (Survey of Kenya 1:250,000 Topo sheet, 2016). Below is the map of the study area in figure 3.1.

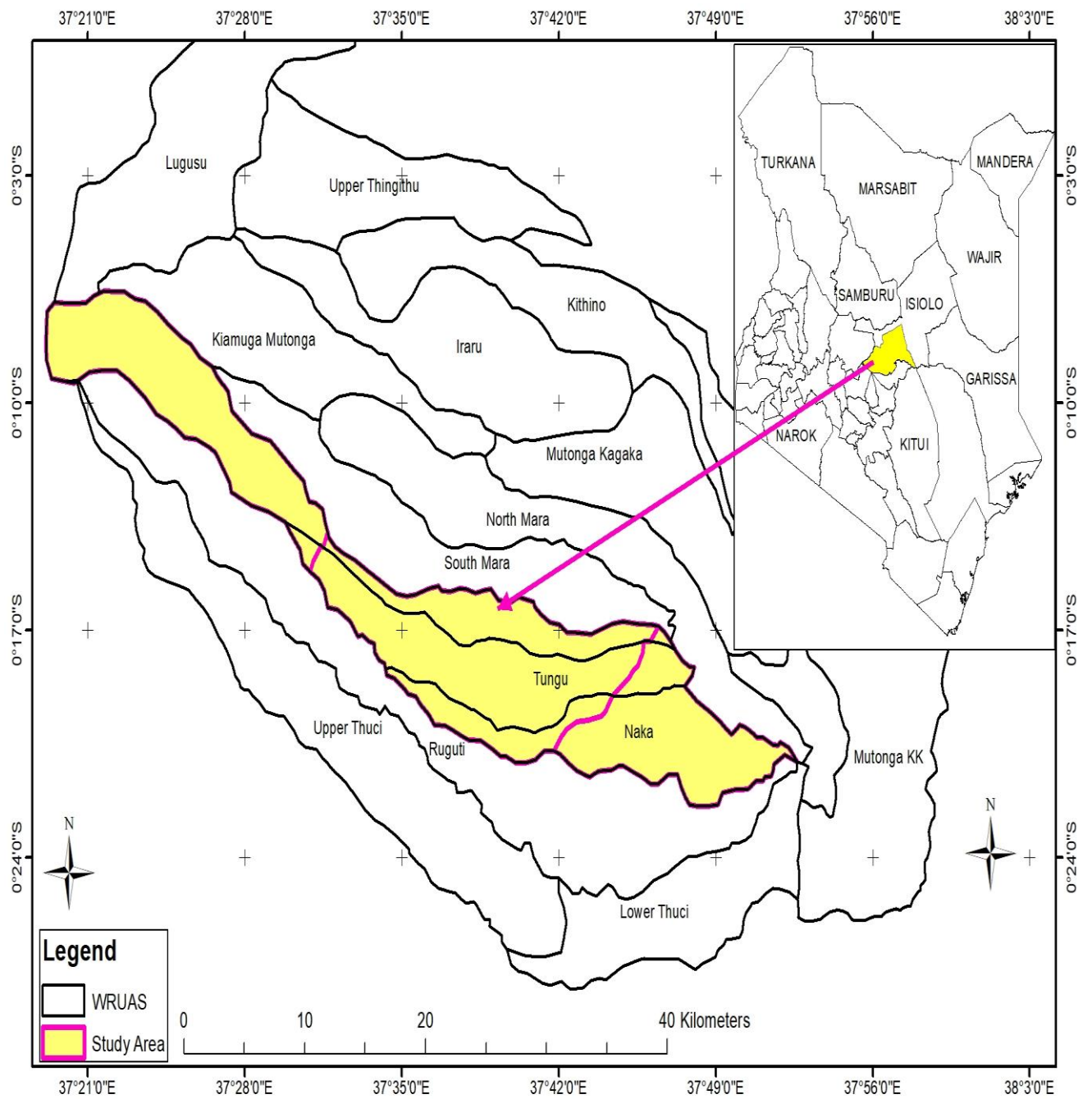


Figure 3.1: Location Map showing the study area

Source: Extracted from (Survey of Kenya 1:250,000 Topo sheet, 2016).

3.2.2 Population

Tungu-Naka sub-catchment has recorded fast population progress, presently at 4 % (GOK, 2017), over the years because of productive land, reliable rainfall, and the establishment of county government offices. The upper region, closer to Mt Kenya forest and the neighboring

region has a faster growth due to the expansion of centres like Chuka and the emergence of Chuka University (GOK, 2017). Smaller towns for instance Kirubia and Mitheru are expanding at a very high rate. The population in the sub-catchment in the previous national census (2009) and 2030 predictions show an incremental rate of 3% per annum (KNBS, 2010).

3.2.3 Climate

The sub-catchment lies between latitude $000^{\circ} 07'$ and $000^{\circ} 26'$ South and longitudes $370^{\circ} 19'$ and $370^{\circ} 46'$ East, with an altitude of 5,200M above sea level. The maximum rainfall within the sub-catchment is 2200 mm, and the temperature ranges between 14°c to 28°c . The watershed experiences a bi-modal rainfall pattern, with the long rains occurring from April to June and the short rains from October to December. As a result of climate change, the rainfall pattern has been altered greatly (GOK, 2017).

The spatial rainfall supply within the watershed can be sub-divided into three regions, namely the upper zone close to Mt Kenya forest, the middle zone and the lower zone. The upper region is very productive and receives rainfall of more than 1700 mm per year. Tea and coffee are the main cash crops. The middle zone is less productive and receives rainfall exceeding 900 mm per year. The key cash crops within the middle zone is Maize, cotton and tobacco. The lower zone comprises of low laying land of Tharaka and livestock is the main occupation with rainfall above 500 mm (GOK, 2017).

3.2.4 Soils and geology

The watershed has ridges on the higher side and several hills and valleys. The soils of the ridges in the water are mainly formed from volcanic parent rock, hence deep red clay (nitisols and andosols). On the lower side there is basement rock system that contains moderately deep to shallow with loam to clay soils (Cambisols, Luvisols and Regosols). The hilly part includes

shallow rocky soils (leptosols). The vegetation in the watershed reflects soils, altitude, relief, and the climate of the region (GOK, 2017).

3.2.5 Hydrology

Tungu-Naka sub-catchment falls under the Tana catchment area and falls under the Kathita Mutonga sub-drainage basin management unit 4EB (WRMA, 2007). Tungu-Naka River originates from Mt. Kenya Forest and flows about 109 kilometres before it joins Nithi at Mariganiro below Kaganjo. Tungu and Naka Rivers are perennial; however, throughout the dry season of February, March, August, and September, water levels are usually very low. This is attributed to high abstractions to support human, livestock, and irrigation demands during this period. All the zones comprise gravity schemes. The area continues to receive a fairly enough rainfall in two seasons: October –December (long rains), and March – May (short rains). Tungu River drains into Nithi, which later drains into Maara, then Thuci, which joins Mutonga, which drains into the Tana River. The sub-catchment is well endowed with springs, streams, and wetlands, but because of the human activities on these water sources, some zones get very little flow during dry spells. Some of the streams include Mitheru, Gancikeru, Kurugucha, Ciiku, Kenywa, Nkobi and Gaciambuga, while wetlands include Nkobi, Gaciambuga, Kamurata, Nkenye, and Kiamugi (Eriani) (WRMA, 2007).

3.2.6 Social economic activity

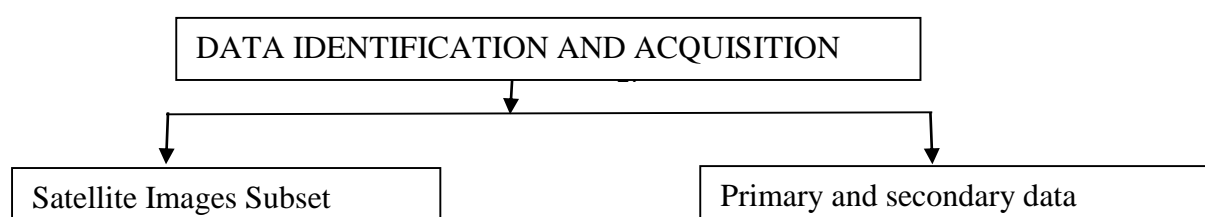
The upper zone of the area under study is enclosed by native montane forest. In the mid-1980s, there was extensive forest logging for business, and as a result, a portion of it was used to form a buffer tea zone (NEMA, 2004; GOK, 2017). Adequate rainfall and productive soils in the upper region enhance farming of crops like coffee, tomatoes, tea, yams, bananas, maize, and beans. Dairy farming is also practiced in form of zero grazing. Goats and beef farming are nurtured (free range) on the lower part of the watershed, which is drier in comparison to other

regions within the watershed. Agricultural factories have dominated the area under study mainly for the primary processing of coffee, tea, and fruit.

Due to an increase in population and extreme farming activities, urban settlement is one of the main land use in the watershed. This has expanded the market of agricultural commodities in the area (NEMA, 2006). Quarrying has also evolved as a land use on all parts of the watershed, emerging as an important land use in the upper, middle and lower catchments where rock outcrops appear mainly for construction stones and gravel (NEMA, 2004).

3.3 Research design

A mixed research design was employed to gather data, utilizing both qualitative and quantitative methods. Qualitative data focused on identifying factors driving land use and land cover change (LULCC) in a watershed, while quantitative data were collected to assess the influence of LULCC on watershed functions and the strategies currently in place for watershed management. This was a specific interview schedule, and questionnaires as shown in Appendix (iv) and (v) respectively. Satellite images were employed in analyzing the LULC trend in the Tungu-Naka sub-catchment between 2002-2018 and the impacts of LULCC. Moreover, photographs were taken of the impacts of LULCC. Document analysis of river discharge data was applied to analyze the impacts of LULCC. Photographs were also taken to show the impacts of LULCC. Below is Figure 3.2 showing research activities in analyzing the LULCC trend in the Tungu-Naka sub-catchment between the years 2002–2018.



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Figure 3.2: Research flow diagram

3.4 Target population

The target population for the research included 35000 households residing in the Tungu-Naka sub-catchment, in Tharaka/Nithi County (KNBS, 2010). The study relied on the household heads and key informants in the watershed to obtain the required data. These informants were picked from WRMA, Tungu Water Resource Users Association (TUWRUA), and the county government minister in charge of water and natural resources.

3.6 Sampling techniques and sample size

3.6.1 Sampling techniques

Due to the large size of the sub-catchment, stratified simple random sampling was used to select 10 villages from each zone within the sub-catchment. In each village, 10 households, specifically the heads of households, were randomly chosen. However, in the last village, only five households were selected due to the sparse population. This process was carried out in the upper, middle, and lower parts of the Tungu-Naka sub-catchment, with assistance from the TUWRUA chairperson. Additionally, purposive sampling was employed to identify key informants from the Department of WRMA, Tungu Water Resource Users Association (TUWRUA), and the county government minister responsible for water and natural resources.

3.6.2 Sampling size

The projected target population of the Tungu-Naka sub-catchment is 135,000 (KNBS, 2010), with an estimated 35,000 households. To determine the sample size, the researcher applied the Krejcie & Morgan (1970) sample size determination formula, as outlined in Appendix V. The following steps guided the process of calculating the sample size:

$$n = t^2 \times \frac{p(1-p)}{m^2}$$

Where;

N = required sample size

T = confidence level at 95 % (1.96)

P = Estimated proportion

M = Marginal error 5% (0.05)

p is determined by;

The total population was approximated at 135000, and the number of households is 35000 (KNBS, 2010).

Therefore, $p = 35000/135000 = 0.259$

$$n = 1.96^2 \times \frac{0.259(1 - 0.259)}{0.05^2}$$

$$n = 3.8416 (0.192/0.0025)$$

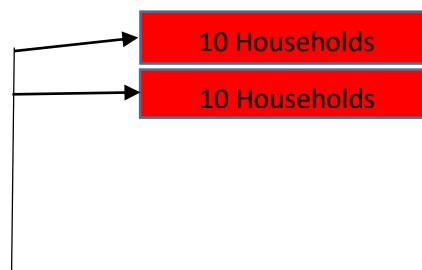
$$n = 3.8416(76.77)$$

$$n = 295 \text{ households}$$

295 respondents (every single person from a household) were selected randomly from the upper, middle, and lower parts of the watershed. The questionnaires were then administered, and 3 key informants were purposively selected for an interview. Figures 3.2 and 3.3 below show the sampling procedure and a diagrammatic representation of the sample area, respectively.



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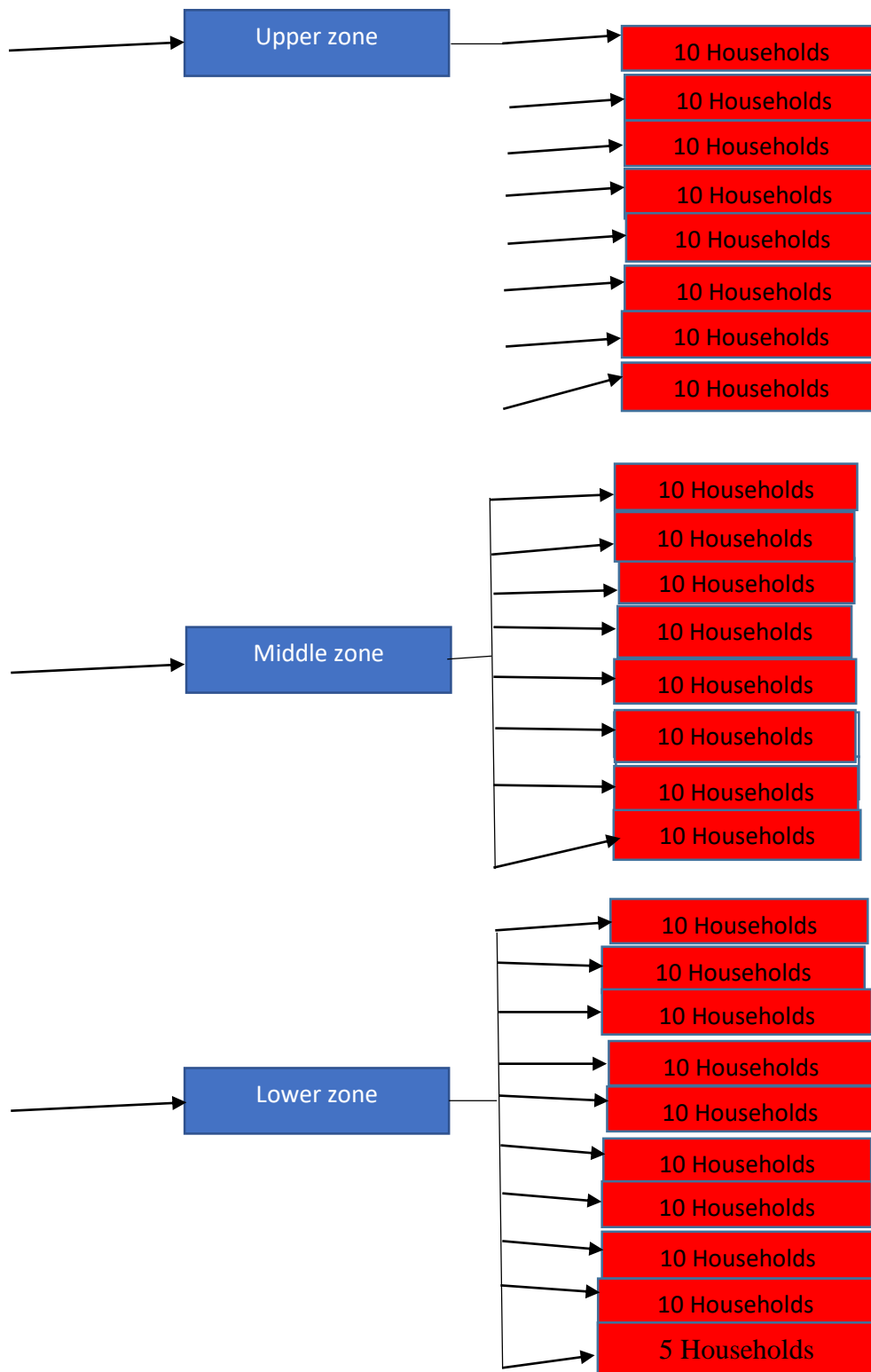


Figure 3.2: Sampling procedure

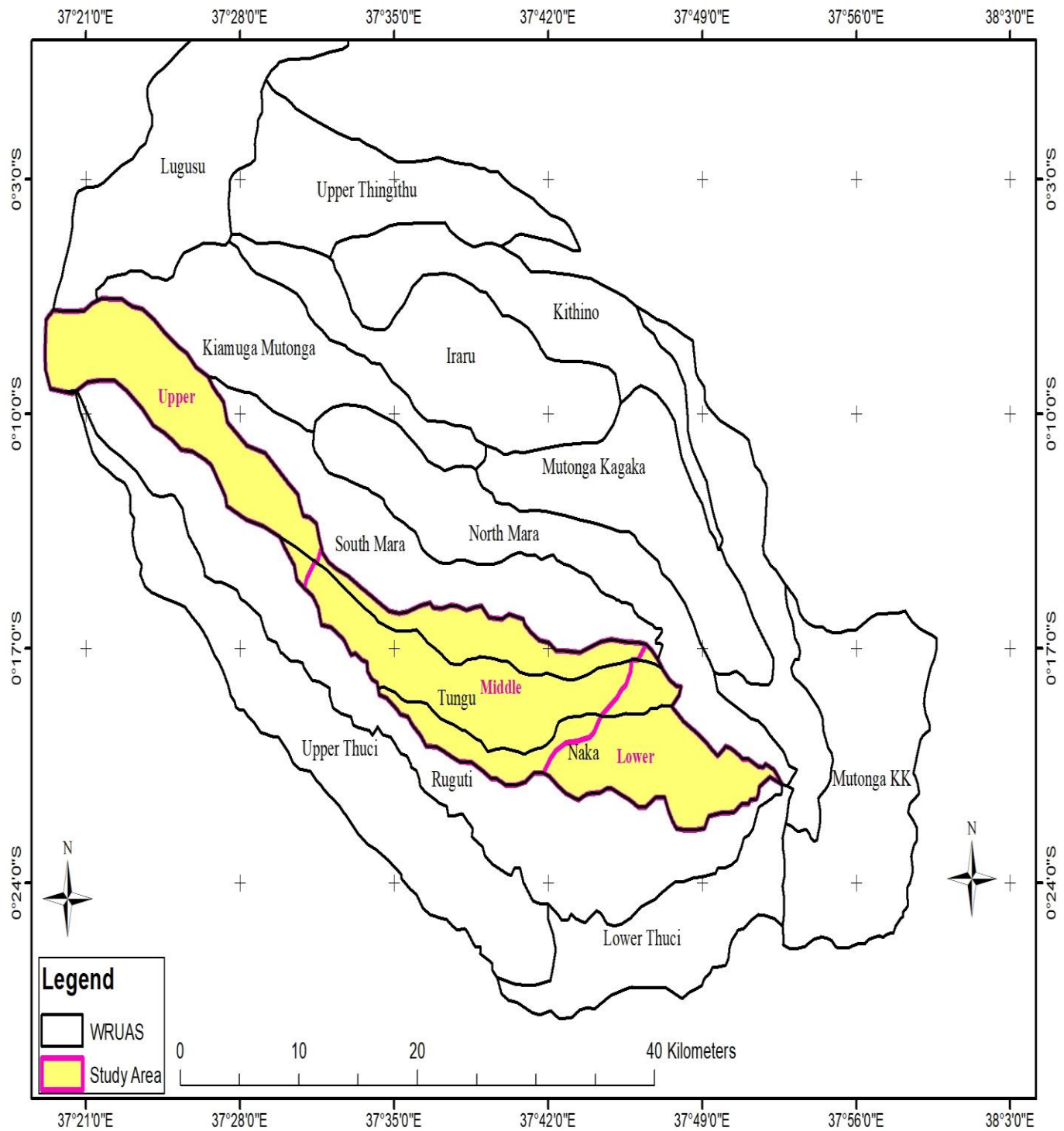


Figure 3.3: Representation of the study area

Source: Extracted from (Survey of Kenya 1:250,000 Topo sheet, 2019)

3.7 Research instruments

Both primary and secondary methods were used to collect and generate data. Primary data was gathered through questionnaires, interviews, and photographs, while secondary data was obtained through document analysis of WRMA records and satellite images.

3.7.1 Interview schedules

The researcher applied interviews (appendix v) to evaluate factors leading to LU/LCC in the Tungu-Naka sub-catchment for the last 16 years in objective two. Furthermore, existing strategies for integrated watershed management in the Tungu-Naka sub-catchment and their effectiveness in objective four were examined. This tool was employed to enhance probing by the researcher to generate sufficient information from the officials concerned. Moreover, employing interview schedules permitted the researcher to seek clarification from the respondent where the response given was not clear or enough. Interview schedules were also important for triangulation purposes.

3.7.2 Questionnaires

Driving factors leading to LU/LCC in the Tungu-Naka watershed between years 2002-2018 (objective ii), the effect of LU/LCC for the last 16 years, and existing strategies for watershed management in the Tungu-Naka sub-catchment and their effectiveness (objective iii), were gathered through questionnaires. The researcher decided to carry out research between the years 200-2018 in order to have a wide range of spatial and temporal periods for LULCC, and to give a clear picture of LULCC. This instrument encompassed closed-ended questions. In closed-ended questions, the participants were given choices of the responses expected (5-point Likert scale). This was employed to allow the gathering of data from many respondents within the shortest time possible, hence saving time.

3.7.3 Landsat Satellite Imagery

To determine the LULC trend in the Tungu-Naka sub-catchment between 2002 to 2018, the research applied four LANDSAT TM imageries of the years 2002, 2006, 2012, and 2018, which were attained from Kasarani Regional Center for Mapping of Resources for Development (RCMRD) and interpreted to give meaning. Krhoda and Kwambuka (2016), employed this method to examine temporal-spatial use change in the Motoine /Ngong river sub-catchment (Chipman, Kiefer, & Lillesand, 2004). On the same objective, the researcher used GPS for ground truthing in the watershed. Moreover, the study employed observation to collect data (taking photographs) on the effects of LU/LCC on Tungu watershed functions, which is the third objective. This instrument was employed for an accurate and clear illustration of the LULC trend from 2002 to 2018, through map-to-map comparison. To achieve objective four, the researcher analyzed data on river discharge in the Tungu-Naka watershed for the last 16 years.

3.7.3.1 Classification of Land Use and Land Cover

Supervised classification was used to analyze land-use/cover changes, as it allows the user to define a training dataset (or signature) that specifies the types of software and pixels to be selected for various land-cover categories. Knowledge of the area, ground truth data, and expertise in image interpretation help in selecting pixels with specific characteristics for more accurate classification (Coppin & Bauer, 1996). Once the signatures were identified, the image pixels were categorized into classes based on these signatures through a classification decision rule. As noted by Coppin and Bauer (1996), the decision rule is a mathematical algorithm that groups pixels into distinct class values using the signature data.

3.7.3.2 Training Data Sets Acquisition and Signature Editing

The satellite images were subsetted, and training datasets were created with the help of aerial photographic interpretation and ground truth data. Aerial photographic interpretation was used to guide the identification of feature classes within the satellite image. The categories defined through this approach included agricultural land, bare land, forest, shrubland, and built-up areas. These classes were extracted from the image using the polygon method, which allows the drawing of polygons to define the locations of pixels representing specific spectral classes. Once the base training sets were established, they were stored in a signature editor and assigned distinct colors for each feature class. These training datasets were then used to generate class signatures and classify the remaining images into meaningful information classes.

3.7.3.3 Change Detection Analysis

The detection of land-use and land-cover changes was conducted by analyzing satellite imagery from the years 2002, 2006, 2012, and 2018. This involved comparing images from the periods 2002–2006, 2006–2012, and 2012–2018 using a confusion matrix. The matrix operation enabled a comparison between two thematic images or vector files from different years, facilitating the identification of changes from one land-use/cover class to another. Landsat data was utilized to analyze the objectives for the periods 2002, 2006, 2012, and 2018.

For change detection and image interpretation, the post-classification comparison method was employed. This technique involved mapping the most recent satellite imagery from 2018, followed by an analysis of the 2002 imagery to track land-use/cover changes over time. Post-classification comparison is one of the most widely used methods for detecting changes in land-use/cover (Hussain, Chen, Cheng, Wei, & Stanley, 2013; Cakir, Khorram, & Nelson, 2006; Coppin & Bauer, 1996; Petit & Lambin, 2001). The land-use change maps were analyzed

through technical procedures using ArcGIS software. This approach helped assess the extent of human impact on the sub-catchment over time and its potential influence on river water flow. Finally, the percentage of land-cover change was calculated using the method outlined by Lambin (2003).

$$\text{Percentage change} = \frac{\text{Observed Change}}{\text{Sum of Area}} \times 100$$

3.8 Pilot study

Research instruments were tested among 30 farmers from the Mwirithie sub-catchment which is within the same region and with similar characteristics to those of the Tungu-Naka sub-catchment. Cronbach's alpha (α) in Table 3.1 was used to run the questionnaires to check on reliability. According to Sekaran (2000), the reliability of data is indicated by the value of r , which ranges from 0 to 1. A higher r value, closer to 1, suggests greater reliability. Sekaran recommends a benchmark of a coefficient above 0.6 for optimal inter-item reliability. If the correlation approaches zero, the instrument is considered unreliable, and adjustments should be made to the items used to measure the different constructs in the questionnaire.

Appendix IV presents the questionnaire used during the pilot study and subsequent data collection. This was done to assess the reliability and validity of the research instrument. The pilot study was conducted three weeks before the main research, allowing sufficient time for any necessary adjustments to the research tools.

3.8 Validity and Reliability of the research Instruments

3.8.1 Validity

Validity refers to how accurately a test measures what it is intended to measure. It reflects the quality, dependability, and trustworthiness of the results in a study. Validity is considered in relation to the test's design, purpose, and the population for which it is intended. The study applied content validity to test the validity of the instruments, through triangulating data from questionnaires and that of interviews. The researcher also received guidance from university supervisors about the validity of research instruments.

3.8.2 Reliability

The reliability of the instruments was assessed using Cronbach's alpha, and it focused on three constructs: factors contributing to land use/land cover (LU/LCC) changes, the impacts of LU/LCC, and the existing strategies for watershed management and conservation, as well as the dependent variable, watershed functions. The collected data was coded and analyzed using SPSS based on the study's variables to compute the alpha value (α). According to Sekaran's (2000) guidelines, a Cronbach's alpha value of 0.6 or slightly lower indicates that the instrument is reliable for measuring the variables. The alpha value was calculated separately for each section of the questionnaire. The results of the reliability test are presented in Table 3.1.

The alpha coefficients for all the variables in Table 3.1 ranged from 0.598 to 0.748, exceeding the recommended benchmark of 0.6. Therefore, the scales were deemed reliable for measuring the variables, allowing the questionnaire to be adopted for the study. Table 3.1 displays the results of the reliability test. For the interviews, the researcher applied member checks, which were found to be very efficient.

Table 3.1: Cronbach's alpha Reliability coefficient

Variable	Constructs	No of items	Alpha
	Factors leading to LU/LCC	8	.716

	Impact of LU/LCC	8	.748
	Existing strategies	7	.684
Watershed functions		6	.598

Source: Survey data (2018)

3.9 Data collection procedure

3.9.1 Land use land cover trend

Four time period Landsat images; two Enhanced Thematic Mapper plus (7 ETM+) and one (1) Landsat 8 image, for the study area for the years 2002, 2006, 2012, and 2018, respectively, were analyzed. They had a spatial resolution of 30 meters and were acquired from the Regional Center for Mapping of Resources for Development (RCMRD) in Kasarani, whereby supervised classification was conducted to provide the trend of LU/LCC for the last 16 years (Rawat & Kumar, 2015; Tendaupenyu, Magadza, & Murwira, 2017; Butt et al., 2015).

3.9.2 Questionnaires

Appendix (iv) presents the open-ended questionnaires that were distributed to the farmers within the sub-catchment area. This assisted the researcher in gathering desired information on factors leading to LU/LCC, impacts of LU/LCC, and the existing strategies for watershed management in the Tungu-Naka sub-catchment, hence the reliability of the results (Eastman, 2001).

3.9.3 Interviews

Appendix (v) includes the interview guide utilized for generating data from the key informants.

One official from WRMA, chairperson of TUWRUA, and the county minister in charge of environment and water resources. The researcher reserved appointments with the key informants for 30 minutes to generate data on factors leading to LU/LCC, impacts of LU/LCC,

and the existing strategies for watershed management in the Tungu-Naka sub-catchment and their effectiveness.

3.9.4 Secondary data

Population data of the study area was acquired from the KNBS repository and analyzed to determine if population is one of the causes of LULCC. The researcher also requested the past daily discharge data from the WRMA from 2002 to 2018 for trend assessment, which was supported by daily discharge data from the TUWRUA secretary. This responds to objective (iii) on the effect of LULCC. Document analysis from WRMA and TUWRUA also provided the existing strategies for watershed management in the Tungu-Naka sub-catchment.

3.10 Data analysis

Qualitative and quantitative methods were applied in analyzing the data. Qualitative data for objectives 2, 3, and 4 was analyzed thematically by initially transcribing, coding, and then organizing into themes according to the responses given. Quantitative data for the same objectives was analyzed through descriptive and inferential statistics (correlation), using SPSS software version 20.2. This was by calculating mean, standard deviation, and percentages for descriptive and correlation for inferential statistics.

The trend of LULCC from 2002 to 2018 was established from satellite imagery through processing (false colors) and clipping of images using Arc GIS 10.3 software, and later the data was saved in Geodata base. The classes comprised a minimum distance supervised classification of settlement, grassland, forest, bare land, agriculture, and wetlands. The researcher then used GPS for ground truth and later drew four land use maps of the area of study from the four images of the years 2002, 2006, 2012, and 2018 (Rawat, Biswas, & Kumar, 2013).

The relationship between independent variables and watershed functions was identified through running data on SPSS using Pearson's product-moment correlation coefficient (r). The study also tested the hypothesis (if $P < 0.05$), then the researcher was to reject the H_0 . This type of analysis was employed because the data generated was nominal. The hypothesis tested was that there is no significant statistical relationship between land use and land cover change and the functions of the watershed in the Tungu-Naka River sub-catchment.

Furthermore, descriptive statistics were employed; frequencies, percentages, and means, and then the outcome was presented through tables according to research objectives.

3.11 Ethical considerations

The researcher first obtained authorization from the university where she is enrolled as a student, and subsequently visited NACOSTI to request additional permission, as detailed in Appendices (i) and (ii). The researcher maintained the privacy of the information gathered from the respondents by ensuring that the tools applied did not bear any form of identification. An elaborate introduction of the researcher was given to the respondents, by giving the name and the reason for the study. Additionally, the researcher assured the respondents that their responses would only be used in academic only. Appendix (VI) shows the consent form that was provided to the respondents for signage that they are at liberty to withdraw from the study, and that they would voluntarily participate in the study. The researcher included a self-introduction section for the respondents. Additionally, a separate introductory letter was provided to the participants alongside the interview schedule. The researcher used Turnitin software to evaluate the thesis similarity index for plagiarism, confirming it was below the 16% threshold recommended by the university guidelines.

Table 3.2: summary of research methodology

No	Objectives	Data required	Data source	Method used	Data analysis
1	To determine land use land cover trend in Tungu-Naka watershed between year 2002 and 2018.	LANDSAT TM imageries of 2002, 2006, 2012 and 2018	Regional Center for Mapping of Resources for Development (RCMRD)	ArcGIS 10.5	Landsat images Classification Change detection analysis
2	To evaluate the factors leading to landuse and land cover change in Tungu-Naka between year 2002 and 2018.	Population data, agricultural data, Abstraction data, rainfall data	WRMA/TUWRU A, KNBS, key informants interviews and questionnaires	Questionnaires, interview schedules, document analysis	SPSS (descriptive & inferential statistics), thematic & content analysis
3	To examine the effect of landuse and land cover change on Tungu-Naka watershed functions.	River discharge, objective data, presence of erosion	WRMA/TUWRU A, key informants interviews and questionnaires	Document analysis, interview schedules, observation, photograph taking	SPSS (descriptive & inferential statistics-correlation), thematic & content analysis
4	To examine the existing strategies for management of watershed in Tungu-Naka sub-catchment and their effectiveness.	Conservation Community groups data. Sub-catchment conservation strategies data	WRMA/TUWRU A, key informants interviews and questionnaires	Document analysis, observation, interview schedules, questionnaire	Content analysis, SPSS (descriptive & inferential statistics) & thematic

Source: Author, 2019

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The study aimed to assess the impact of Land Use/Land Cover Change (LULCC) on watershed functions within the Tungu-Naka sub-catchment. It focused on analyzing the LULCC trend between 2002 and 2018, exploring the effects of these changes on watershed functions, identifying the driving factors to the changes, and evaluating the conservation and watershed

management measures implemented. This chapter presents the findings of the study, structured around the four primary research objectives.

The results are discussed based on both quantitative and qualitative data collected. The section includes the presentation of land use maps, descriptive and inferential statistics, as well as thematic analysis from interview transcriptions. In addition to questionnaires, qualitative data was obtained through interviews, with audio recordings transcribed and analyzed to identify key themes. Triangulation was conducted using classified Landsat images to create land use maps, and the two data sets were presented separately before being merged for interpretation and discussion, ensuring triangulation and complementarity. Direct quotes from the key informant interviews (KII) are included to support the major themes and issues identified.

4.2 Interview Data Analysis

4.2.1 Overview of Participants

Individual interviews took place with the WRMA officer in charge of water resources and the TUWRUA chairman. Individual respondents' quotes were identified through the codes as per the following list to ensure anonymity and confidentiality. Letter (R) was used to label the respondents who participated in the study. Two interviews were identified using letters (I) and numbers (1-2) to represent the two distinct interviews. The study findings were presented by identifying the participants according to the assigned letters and numbers in the various interviews. For example: I1R: Interview1, respondent in the discussion. Fig 4.1 gives an overview of themes and sub-themes identified from the interviews for objective 2, 3 and 4.

4.2.2 Themes and subthemes identified

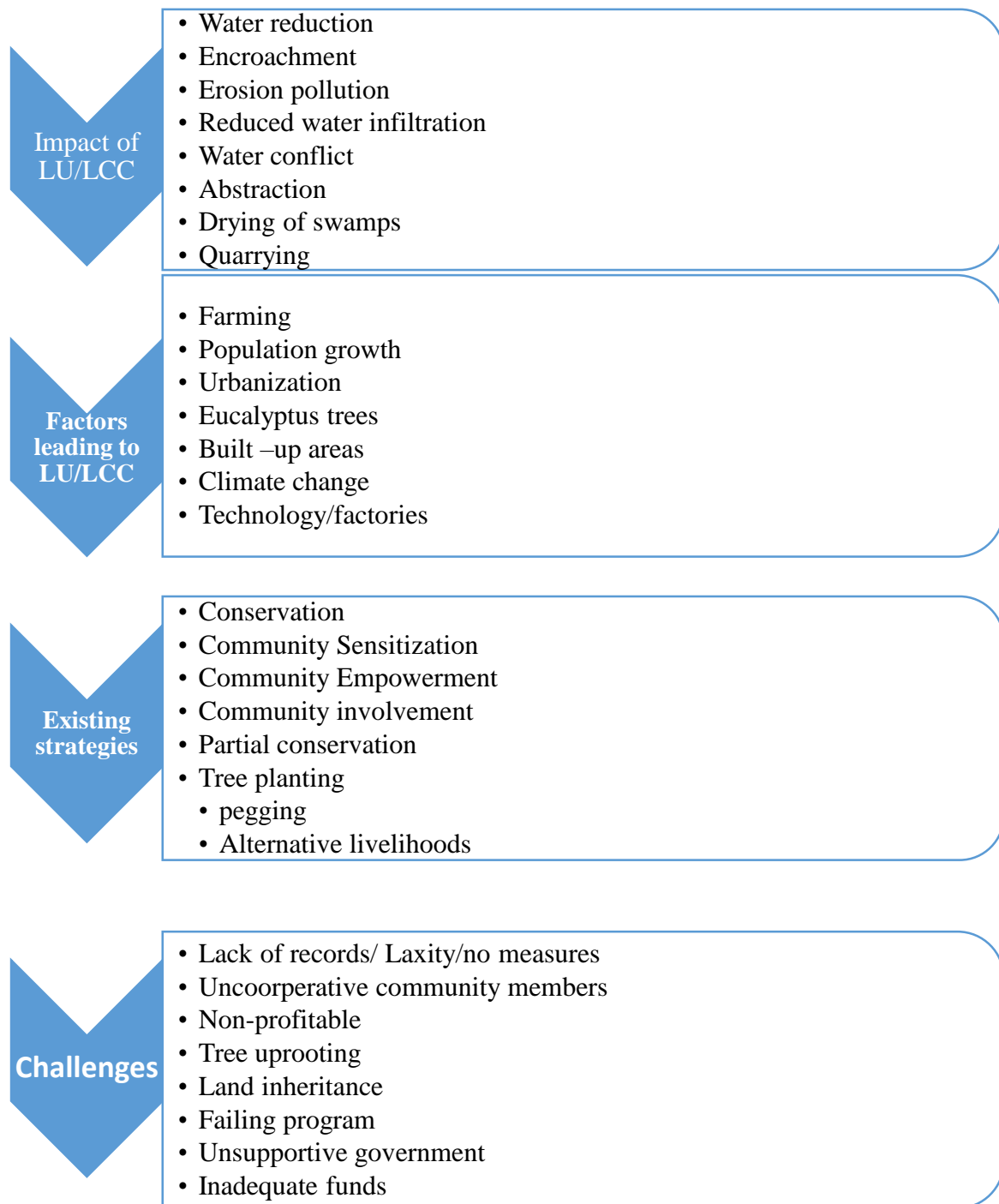


Figure 4.1: Interview summary for objectives 2, 3 and 4

4.3 Objective 1: Land-Use and Land-Cover Change between 2002 and 2018

To establish the land use land cover trend in the Tungu-Naka watershed between 2002 and 2018, various land uses were mapped out from satellite images. After that, the researcher came up with land use maps for the respective years. Ground truthing was conducted, and the accuracy assessment of the interpretation was done. ArcGIS 10.3 and ERDAS Imagine 9.1 software were applied to extract land cover information and further analysis of relationships, patterns, and trends in a multi-temporal approach.

To identify changes in land use and land cover over time, it is recommended to use data sets from at least two different time periods (Jenson, 1986). In this study, four time period Landsat images; two Enhanced Thematic Mapper plus (7 ETM+) and one (1) Landsat 8 image, for the study area for the years 2002, 2006, 2012, and 2018, respectively, were analyzed. The images were downloaded from the USGS Landsat Global Visualization Viewer.

The Land use/land cover maps were produced from the satellite images by defining spectral classes by image data clustering and assigning pixels into classes. Multi-temporal Landsat data processing was done using ENVI 4.7 software (ESRI, 2009). Regions of Interest (ROI) were defined to extract statistics for classification. The four (4) period Landsat imageries were classified through the supervised classification technique, with false color composite bands (4, 3, and 2) to cluster pixels in a dataset into classes. Six land use classes were established according to Anderson (1976) guidelines as Agricultural, Forest, Grassland, Wetland, Bare land, and Settlements.

The analysis of ground truth data collected during fieldwork and classified Landsat images from 2002, 2006, 2012, and 2018 reveals notable changes in land use and land cover within the sub-catchment. The results presented in Tables 4.1 and 4.2 indicate significant transformations in land use and land cover patterns between 2002 and 2018.

Table 4.1: Distribution of Land Use and Land Cover from 2002 to 2018.

<i>CLASSES</i>	<i>2002 Area (Ha)</i>	<i>2006 Area (Ha)</i>	<i>2012 Area (Ha)</i>	<i>2018 Area (Ha)</i>
Agriculture	16339.032	15835.406	15925.004	16273.917
Forest	10194.390	9554.580	9409.590	9267.110
Grassland	6951.330	7213.950	7693.810	7309.180
Wetland	0.450	0.240	0.190	-
Settlement	156.268	182.474	394.816	448.253
Bareland	1530.350	2185.170	1748.410	1873.360
Total	35171.820	35171.820	35171.820	35171.820

The distribution of the areas covered by various LULC categories in the years 2002, 2006, 2012 and 2018 are presented in Figure 4.1 (a-d).

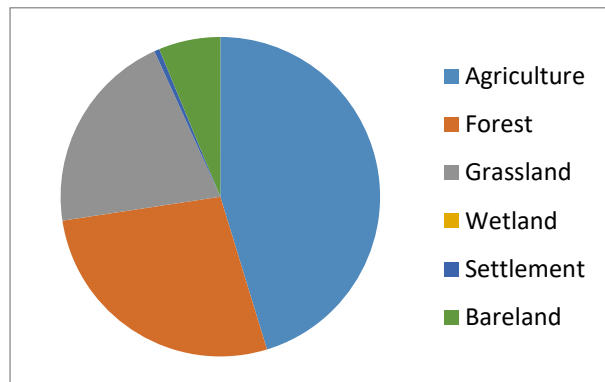


Fig 4.1(a) 2002

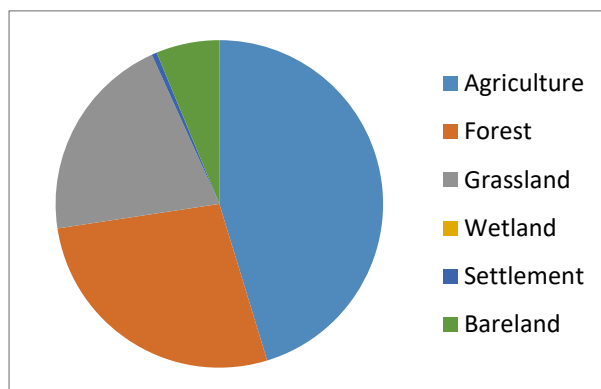


Fig 4.1 (b) 2006

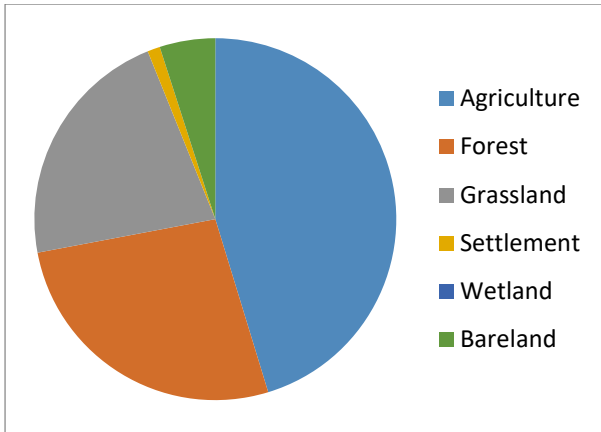


Fig 4.1 (c) 2012

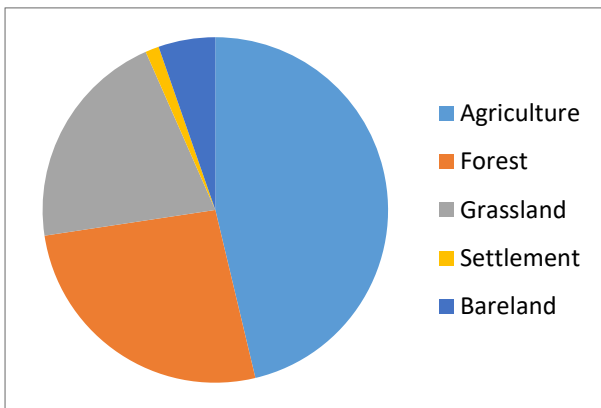


Fig 4.1 (d) 2018

Figure 4.1 Computed land use/cover use for year 2002, 2006, 2012 and 2018

Between 2002 and 2018, the watershed experienced various changes in land use and land cover. In 2002, agricultural land covered 16,339.032 hectares, which decreased to 15,835.406 hectares by 2006, marking a decrease of -0.566%. However, by 2012, agricultural land expanded to 15,925.004 hectares and further increased to 16,273.917 hectares in 2018. The reduction in agricultural land between 2002 and 2006 may have been driven by the rising demand for settlement land. On the other hand, the subsequent growth in agricultural land could likely be attributed to population growth, which led to a higher demand for food in the watershed.

On the other hand, the region covered by forest was 10,194.390 Ha in 2002 and declined to 9,554.580 Ha. 2006. 9,409.590 Ha in 2012 and reduced further to 9,267.110 Ha in 2018. There has been a continuous reduction in the region covered by forest in the years under study. This

can probably be connected to growth in population, hence demand for settlement land and farming land to increase crop production. According to all the Landsat images, the upper region is more forested compared to the lowland, meaning that there are additional agricultural activities in the lowland compared to the higher regions, though part of it is on the reserved forest zone.

Conversely, settlement land has gradually been rising from the years 2002, 2006, 2012 and 2018. In 2002, it was 156.268 Ha and 2006, 182.474 Ha 2012 394.816 Ha and 2018 is 448.253 Ha. The intermediate part of the sub-catchment seemed to be more populated compared to other parts. Expanded settlement land could be as result of population growth as it was evident from Kenya National Bureau of statistics table 4.2.

Table 4.2: Tungu/ Naka watershed 1999 and 2009 Population Data

Year	1999			2009		
	Male	Female	Total	Male	Female	Total
Kiang'ondu	5793	6032	5903	7041	7647	14688
Mugwe	3113	3321	6434	51173	5362	10535
Karingani	4025	6071	10096	9022	9172	18194
Kithangani	1112	1697	2809	2152	2230	4382
Gitareni	2995	3022	6017	4102	4488	8590
Muiru	1413	1610	3023	2487	2573	5060

Source: KNBS 1999/2010

Furthermore, the region covered by the wetland was 0.450Ha in 2002, 0.240 Ha in 2006,

reduced further to 0.190 Ha in 2012, and in 2018 became negligible, hence could not be captured in the Landsat image. These results are similar to the interview outcomes, where the chairman of the TUWRUA mentioned that almost all the wetlands in the watershed have dried up due to rigorous farming activities going on in the region. Moreover, document analysis from the TUWRUA (2018) report had similar results.

Contrary, the region occupied by grassland seemed to have expanded in 2012, and then in 2018, it reduced. In 2002, its region was 6951.330 Ha; then it expanded to 7213.950 Ha in 2006, in 2012 it was 7693.810 Ha, and in 2018 it had declined to 7309.180 Ha. The reduction in the area occupied by the grassland could have been attributed to the upsurge in the percentage of bare land or an increase/decrease in the amount of rainfall between 2012 and 2018, hence part of the grassland being converted to bare land and settlement as well.

Furthermore, in 2002 bare land area was 1530.350 Ha, in 2006 it expanded to 2185.170 Ha, in 2012 it reduced to 1748.410 Ha, and in 2018 it increased to 1873.360 Ha. The growth of bare land could have emanated from the expansion of learning institutions in the area covered by grassland in the same Landsat image, maybe due to demand for more land for settlement in the sub-catchment.

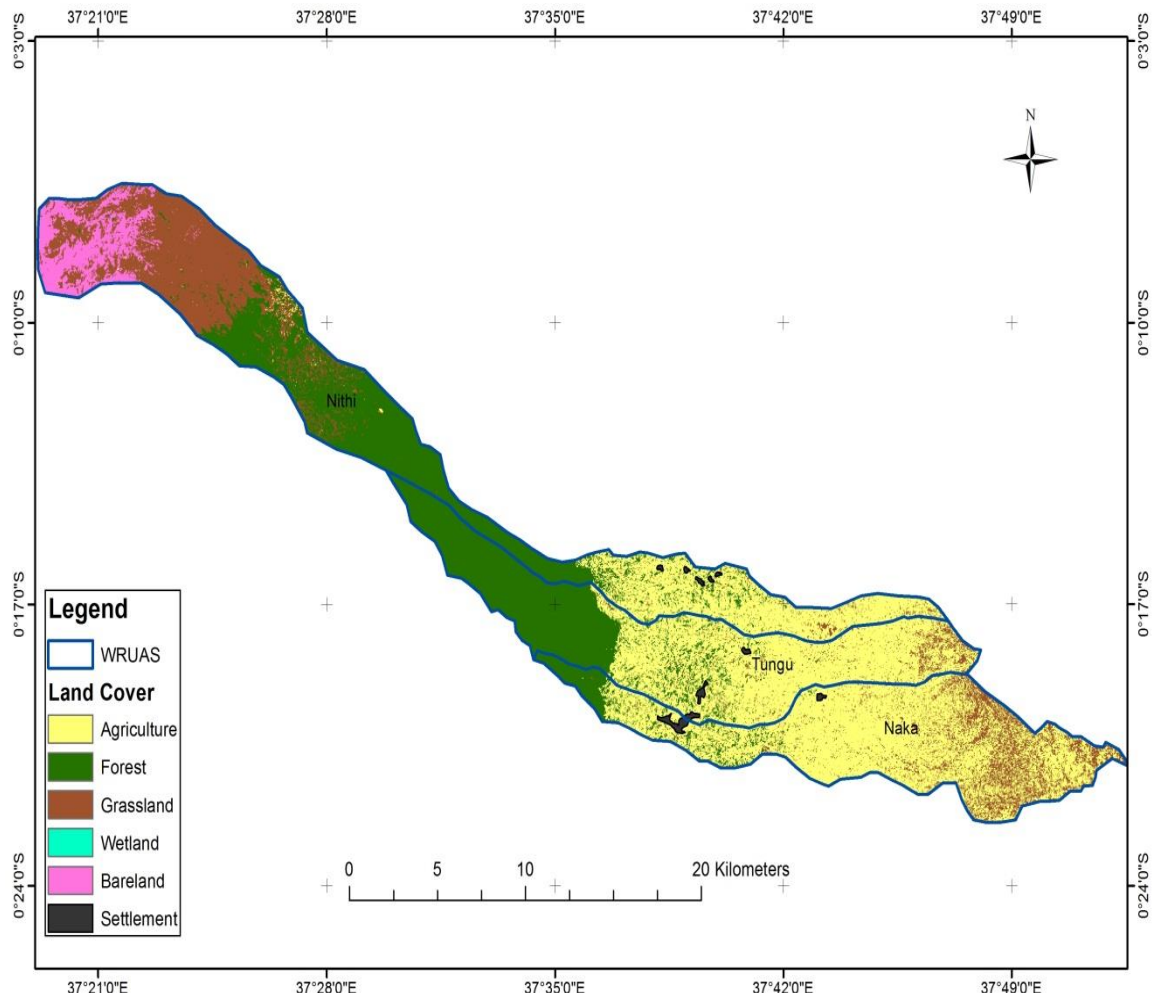


Figure. 4.2 Landuse map for 2002

Source (Author 2018)

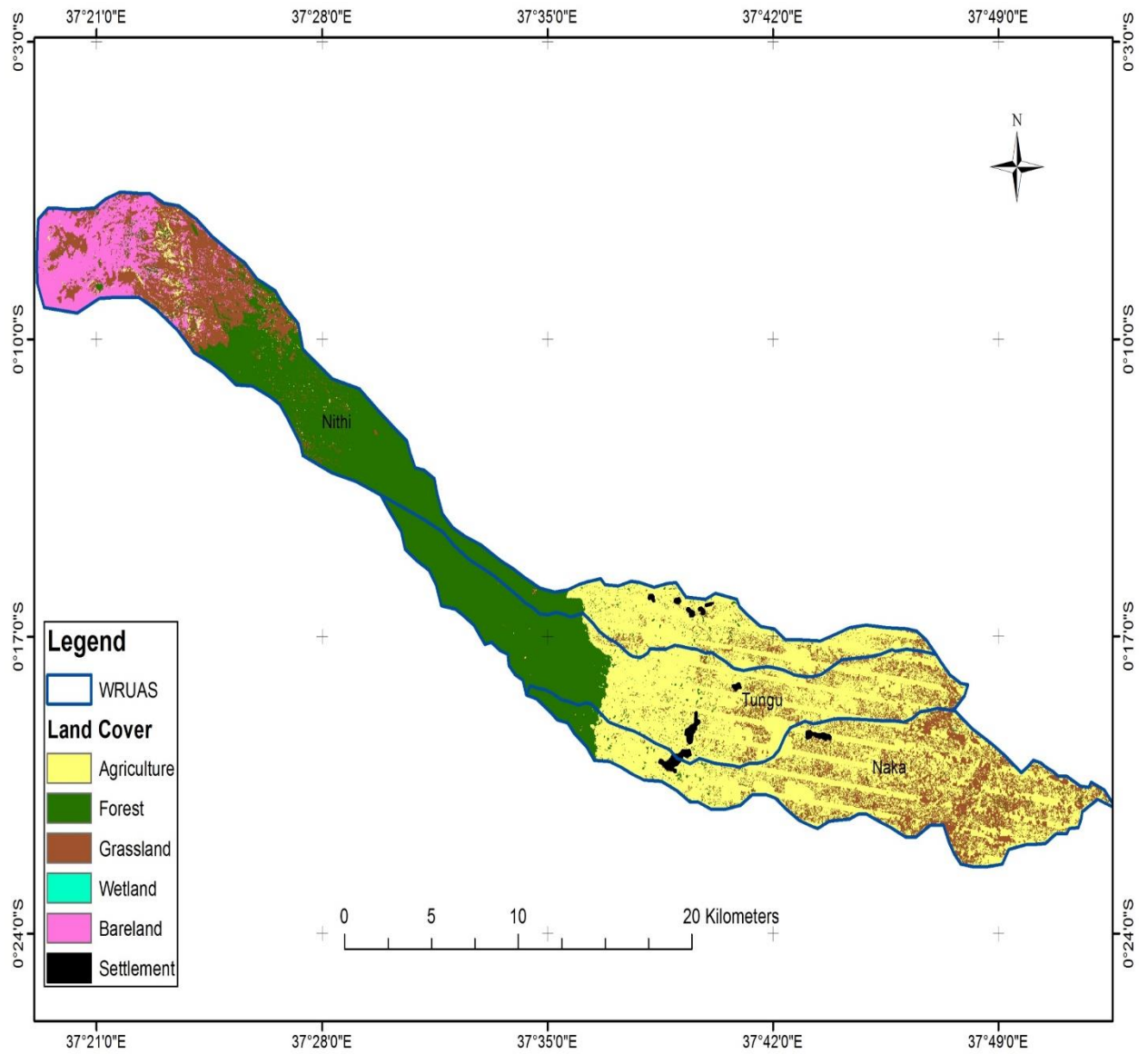


Figure. 4.3 Landuse map for 2006

Source: Author

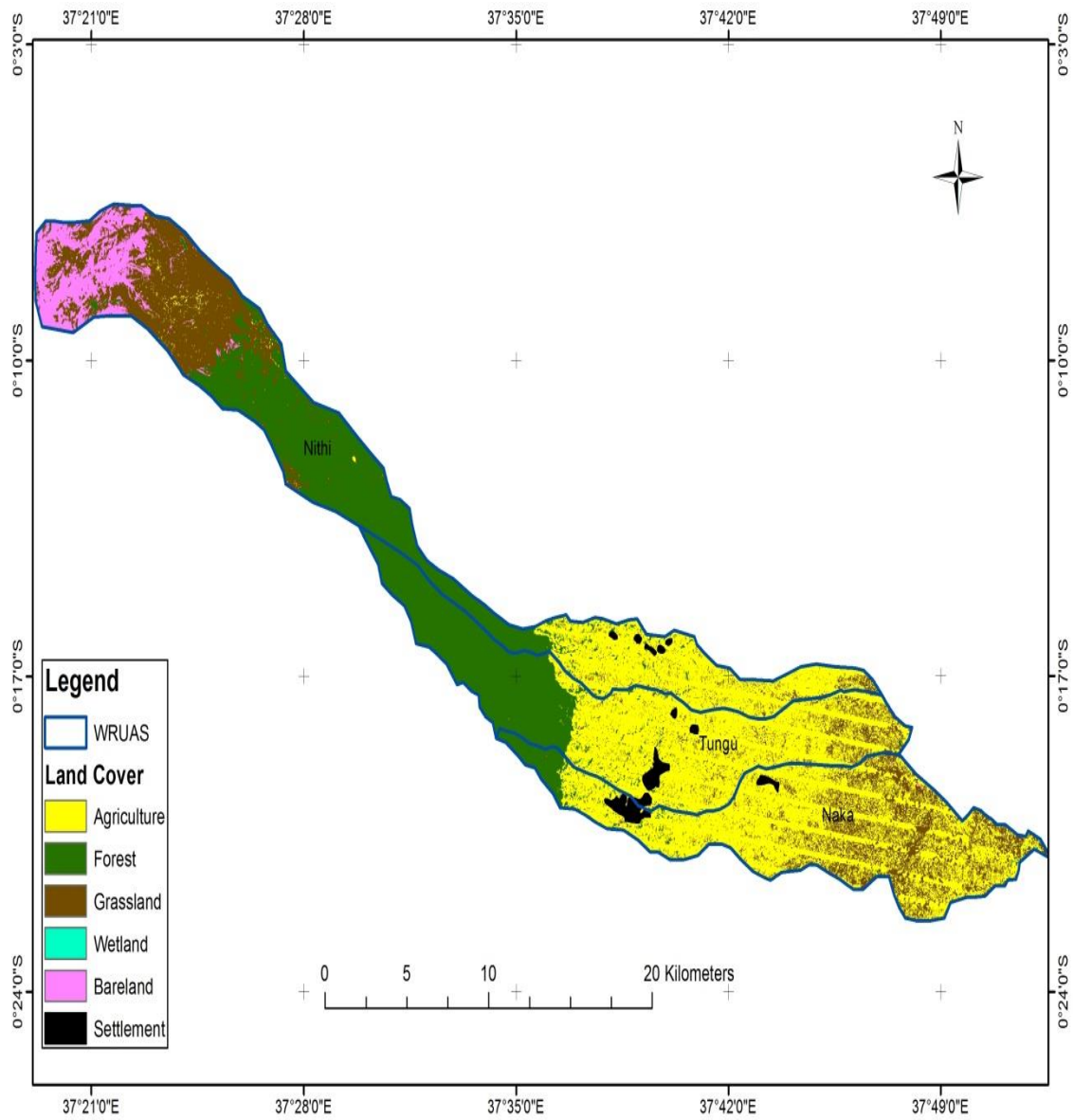


Figure. 4.4 Landuse map for 2012

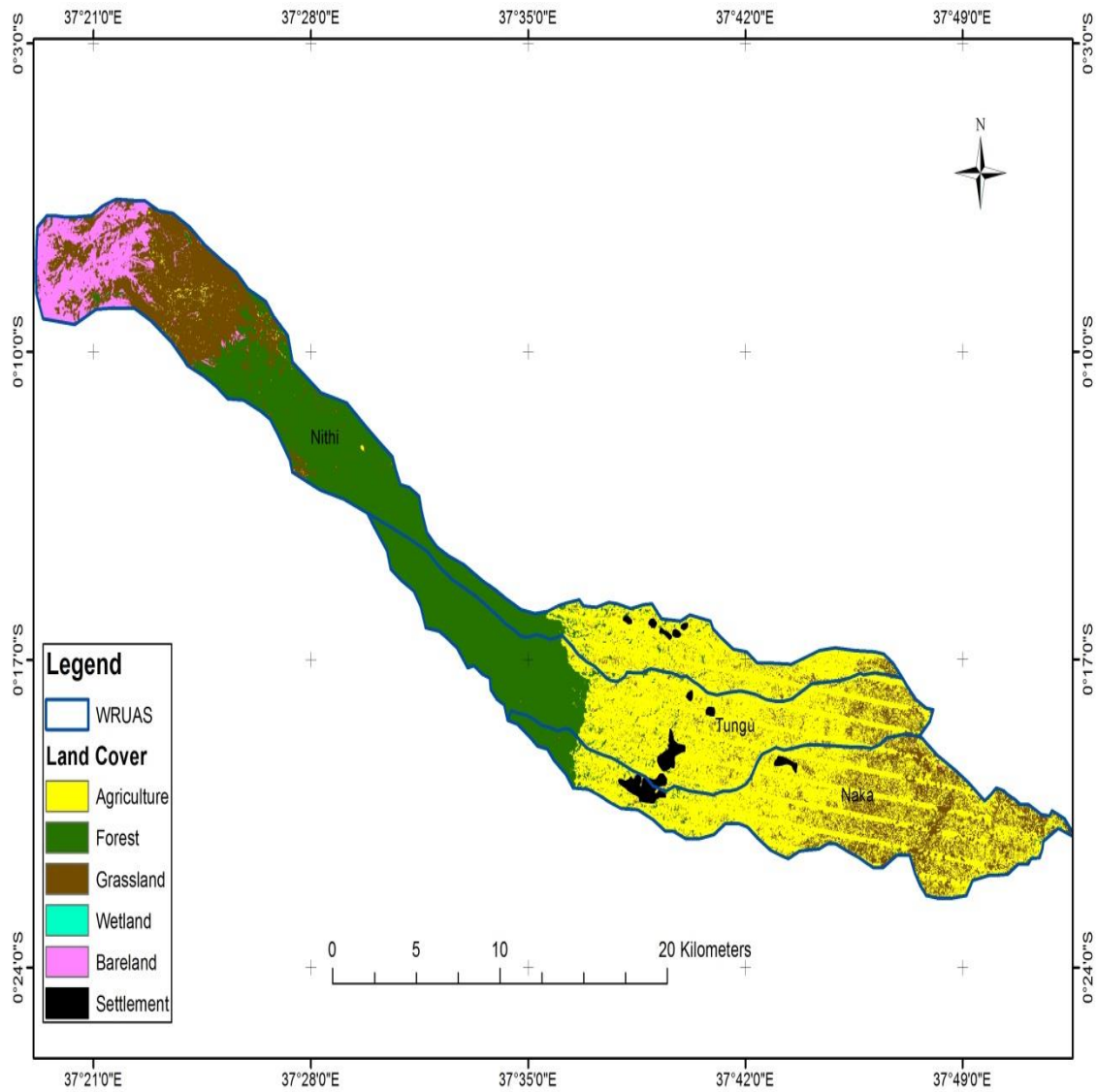


Figure. 4.5 Landuse map for 2018

Change detection was done for the classified land use and land cover types. ArcGIS 10.5 Software (ESRI, 2009) was applied for thematic change detection of images of different time periods (2002, 2006, 2012, and 2018 images), and the results are shown in the table below.

Table 4.3 Percentage change

CLASSES	2002 - 2006 Area (Ha)	% Change	2006-2012 Area (Ha)	% Change	2012 -2018 Area (Ha)	% Change
Agriculture	503.626	3.082	-89.598	-0.566	-348.913	-2.191
Forest	639.81	6.276	144.99	1.517	142.48	1.514
Grassland	-262.62	-3.778	-479.86	-6.652	384.63	4.999
Wetland	0.21	46.667	0.05	20.833	0	0.000
Settlement	-26.206	-16.770	-212.342	-	-53.437	-
Bareland	-654.82	-42.789	436.76	19.987	-124.95	-7.146

The results also revealed that from 2002 to 2006, the region covered by agriculture changed positively by 3.082%, from 2006 to 2012, there was a negative change of -0.566% while in 2012 to 2018, a percentage change of -2.191%. This change was contrary to the region under forest that changed with 6.276% from 2002-2006, 1.517% from 2006-2012, and 1.514% from 2012-2018. This constant positive change means that the region under forest has been dropping continuously from 2002 to 2018, which might have been ascribed to population growth and demand for farming and settlement land in the sub-catchment under study. For the grassland, the percentage change from 2002-2006 was -3.778%, -6.652% from 2006-2012 and 4.999% between the years 2012-2018. This positive change could have been contributed by a reduction in the bare land and the area covered by forest. Moreover, there has been a massive percentage change in the area covered by wetland, whereby 46.667% was realized in 2002-2006, 20.833% in the years 2006-2012 and 2012-2018, the area under wetland was so negligible that it could not be noticed from Landsat images that were useful in the current study, hence 0% change. Consequently, there was a consistent negative percentage change on the three levels of comparison in the area under study. In 2002-2006, there was a percentage change of -16.770%, -116.368% from 2006-2012, and -13.535% in 2012-2018. This is attributed to population expansion in the sub-catchment under study, as evidenced in Table 4.2.

Change detection trend was performed for the classified land use and land cover types and analyzed graphically as indicated in Figure 4.6. This shows the increase and reduction in the land use and land cover.

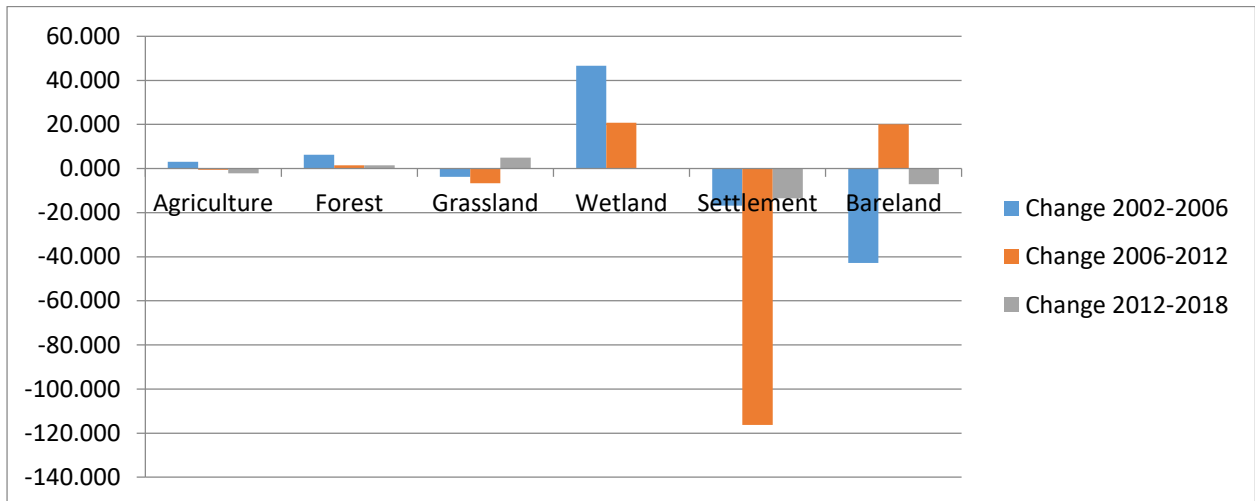


Figure 4.6 LULC Change analysis graph

From the classification of Landsat images of the years 2002, 2006, 2012, and 2018, there is evidence of substantial alteration in land use and cover change in the Tungu-Naka sub-catchment. The findings showed that the region covered by forest has declined significantly, as the area under settlement expands. The reduction in the area under forest could be related to high demand for settlement land and agriculture, as well as people cutting trees to create more space for farming and settlement. Quantitative data had similar results, a high demand for farming and settlement land in the sub-catchment under study. Moreover, interview findings also reported an increased demand for agricultural land as well as settlement in the sub-catchment, hence leading to the conversion of riparian land into farming grounds.

The reduction in the forest area and growth in of settlement coincides with the findings of the Indian research on the changes in LU/LCC through the geospatial method in Ramnagar town area. The research found that from 1990 to 2010, the built-up area raised by 8.88%, and vegetation decreased by 9.41% (Rawat, Biswas, & Kumar, 2013; Rawat & Kumar, 2015; Rwigi

et al.,2024). Similar findings were observed in the Weruweru-Kiladeda sub-catchment research within the Pangani River basin, Tanzania, where forest cover reduced as agricultural land expanded, impacting soil water infiltration rates (Renny Chiwa, 2008). A similar trend was found in the Mutonga sub-catchment in Kenya, where forested areas shrank as urban development increased (Njoka, 2012).

Furthermore, between 2012 and 2018, agricultural land in the region decreased as settlement areas expanded. This could be attributed to the population growth within the sub-catchment, leading to a higher demand for food and housing. According to the Kenya National Bureau of Statistics (KNBS) 1999, the population in the area increased by 20% by 2009, and based on projections from the 2019 census, it was expected to have grown by over 25%, largely due to urbanization in the region (Wardrop et al., 2018).

Contrary to the above findings, research done on the changes in LU/LCC through geospatial method in Ramnagar town area found that as the built-up area enlarged, the agricultural land reduced, and the explanation was that population growth gave pressure to farming land, hence causing the decline (Rawat et al., 2013).

Furthermore, the wetland was seen to have declined progressively from 2002 to 2012, and the Landsat image of 2018 could not locate any wetland in the watershed under study. The findings agree with Butt et al. (2015), meaning that the wetlands have dried up within the watershed under study. From the interview data, the latter was related to the encroachment by community members as they create more land for farming. In support of the above allegation, one of the respondents said the following:

“People are drying wetlands so that they can farm because of the growth in population so they are creating land for farming.”I2R/L3-5/P.3)

Document analysis from TUWRUA also ascertained that the wetlands in the sub-catchment have dried up due to the planting of eucalyptus trees and other farming activities by society members.

Land use and land cover trends have been changing continuously in different classes examined, and the change is either positive or negative. From the findings, forest cover and built-up area have been changing positively from 2002 to 2018. This is an indication that watershed functions have been interfered with since low forest cover encourages more surface runoff due to low infiltration rate (Gumindonga, 2010).

4.4 Objective 2: Factors leading to LU/LCC

4.4.1 Response Rate

The research targeted 295 respondents, and data was successfully collected from 238 participants, yielding a response rate of 80.68%. This response rate is considered acceptable, as it exceeds the threshold of 70%, which is deemed excellent (Kothari, 2004). A higher response rate reduces the margin of error and enhances precision (Malhotra, 2007).

4.4.2 Respondent Profile

The demographic profile of the surveyed respondents, including gender and age, was presented in Table 4.4. In terms of gender, 61.4% of the respondents were male, while 38.6% were female, indicating that a larger proportion of females did not participate in filling out the questionnaires. Regarding age, 10.1% of the respondents were under 24 years old, 25.6% were in the 25-34 age group, 25.6% were in the 35-44 age group, 26.9% were in the 45-54 age group, 23.1% were in the 55-64 age group, and 1.3% were over 65 years old.

Table 4.4: Demographic Profile of the Respondents

Variable	Category	Frequency	Percentage
Gender	Male	146	61.4
	Female	92	38.6
Age	Below 24	24	10.1
	25-34	61	25.6
	35-44	64	26.9
	45-54	55	23.1
	55-64	31	13.0
	Above 65	3	1.3
	Total		238

Source: Survey data (2018)

Descriptive statistics, including means, standard errors, and standard deviations, were calculated for variables related to the factors leading to land use and land cover change (LU/LCC), the impact of LU/LCC, existing strategies, and watershed functions.

To assess the driving factors contributing to LU/LCC in Tungu-Naka between 2002 and 2018 (objective two), descriptive statistics were applied. The means for the items related to factors leading to LU/LCC ranged from 3.2286 to 4.4857, with an overall mean of 3.8646. This indicates that the scores were above average on a 5-point Likert scale. The standard deviations ranged from 0.87346 to 1.39535, and the overall standard deviation for these factors was 0.66597. The relatively low standard deviation suggests that the spread of scores was narrow. The small standard errors of the mean indicate that the mean values for these items were reliable. The highest mean was found for the item 'high demand for farming land has highly contributed to drying of wetlands in the watershed' (FLULCC4), while the lowest mean was for 'some parts of the watershed are bare due to high demand for charcoal and firewood' (FLULCC7). The descriptive statistics for these factors leading to LU/LCC are presented in Table 4.5.

Table 4.5: Descriptive Statistics for factors leading to LULCC

Code	Item	Mean		SD
		Stat	SE	
FLULCC1	High demand for food has intensified small scale irrigation in the watershed	3.7857	.14939	1.24984
FLULCC2	population growth has led to clearing of riparian	3.9000	.13521	1.13124
FLULCC3	Advancing technology has encouraged farming of faster maturing crops	4.0000	.12544	1.04950
FLULCC4	planting of eucalyptus has highly contributed to drying of wetlands	4.4857	.13304	1.11307
FLULCC5	I am ignorant of sustainable utilization of the watershed.	4.0714	.12597	1.05393
FLULCC6	Ready market for timber has led to cutting down trees to earn a living.	3.3714	.15115	1.26458
FLULCC7	Some parts of the watershed are bare due to high demand of charcoal and firewood.	3.2286	.16678	1.39535
FLULCC8	low crop output from rain fed agriculture has made us shift to irrigation	4.0714	.10440	.87346

Source: Survey data (2018)

From the statistical means calculated, 77% of respondents agreed on the listed factors leading to LU/LCC in the Tungu-Naka sub-catchment. This was evident from the low mean and statistical standard deviation displayed by the item. The item on planting eucalyptus has highly influenced drying of wetlands, had the greatest mean of 4.49, meaning that 89.7% of respondents agreed with the statement. This finding aligns with a recent court ruling in Kenya that banned the planting of eucalyptus trees near water resources (*Nation Media Group, 2025*). From the statistics, farming and population growth were found as key contributors to LU/LCC

in the Tungu-Naka sub-catchment. These findings were similar to those of other interviews as follows;

“Most of encroachment is as a result of farming.” (IIR/L18/P.1)

“People are farming all the way to river system, up to the riparian land.” (IIR/L19-20/P.1)

“These people cleared all the riparian land due to farming.” (I2R/L8/P.1)

Moreover, 78% of respondents confessed that population growth in the sub-catchment influenced LU/LCC to create additional land for settlement and food. The above findings concur with a study conducted in Ghana that expansion in demand for food, fuel, and raw materials has led to local and global pressures for land use (Brown, Hammill, & McLeman, 2007). However, (Iro, 2015) disagrees with the above study that the largest part of the watershed was degraded as a result of farming, and instead, supports that the increase in the built-up area contributed the largest percentage to watershed degradation. This was a similar finding from the interviews where the respondents said the following;

“The issue of population has a negative impact on the sub catchment because there is an increase in the built-up areas especially the coming up of Chuka University and also the establishment of county government.” IIR/L2-4/P.4)

“Emergence of Chuka University has forced development of many hostels in the area, you know when we start having many concrete slaps.” I2R/L22-24/P.2)

“People are drying wetlands so that they can farm because of the growth in population so they are creating land for farming.” I2R/L3-5/P.3)

“Along Tungu river the place so much populated compared to the past years.” I2R/L23-24/P.3)

The above findings agrees with a study done in China, that rapid economic development, growth in population and urbanization had led to landuse changes hence accelerating the diminishing of water resources (Nian, Li, Zhou, & Hu, 2014; Abebe, 2018). Partly, these findings agree with the conclusions of a study conducted in Ngong River that, that population and economic expansion result to expansion of towns spatially, hence channel erosion and change in river flow (Krhoda & Kwambuka, 2016; Ayivor & Gordon, 2012).

In addition to the above, improvement in technology was mentioned as one of the factors leading change in farming styles hence land use change.

“The new crops which the community members are growing along the river are shallow rooted so when erosion takes place is so massive.”(I1R/L15-16/P.3)

Consequently, one of the respondents stated that climate change has also contributed to LU/LCC in the watershed.

“Climate change has also been a challenge for us for the last four years, the banks were open with no vegetation hence the rate of evaporation was so high.”I2R/L11-12/P.3)

The study found that intensive agriculture and growth in population as the key contributors to LU/LCC in Tungu-Naka watershed. This was linked to the demand for food and construction land. The balance between the two can be achieved sustainably without threatening the sub-catchment. However, strain of natural resources as a result of high population and demand for food forced encroachment in the sub-catchment. In summary, to evaluate the listed factors leading to LU/LCC, demand for timber, especially eucalyptus, was ranked the highest contributing factor to the change, followed by population expansion within the watershed. Expansion of agricultural land, especially due to irrigation, was the third factor contributing to

LU/LCC. Use of trees for charcoal and firewood was the fourth factor, and finally, advanced technology. The rating was according to the responses given in the questionnaires as shown in Figure 4.7 below.

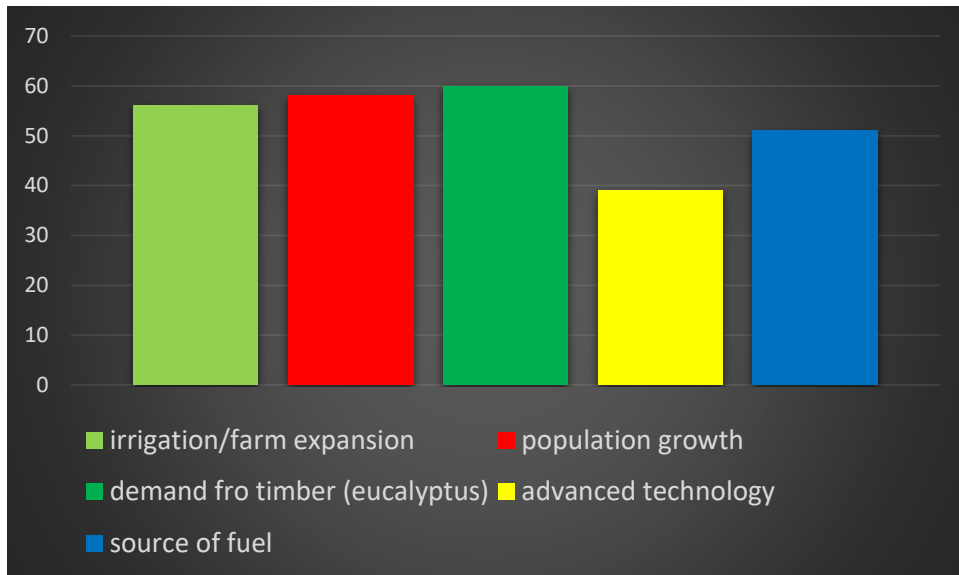


Figure 4.7: summary of the factors leading to LU/LCC

4.5 Effect of LULCC

The descriptive statistics for the items measuring the effect of Land Use and Land Cover Change (LULCC) indicated that the mean values ranged from 2.9429 to 4.4429, with an overall mean of 3.6804. All scores were above average on the 5-point Likert scale, and the standard deviations varied between 1.01633 and 1.68442. The general standard deviation for the impact of LULCC was 0.74868, suggesting low variability in the spread of the scores.

The standard error of the mean was 0.08948, which reflected the reliability of the mean values for the items. A closer examination of individual items showed that respondents rated the statement "over abstraction of water from the river reduces water quantity" (ILULCC2) the highest, with a mean of 4.4429 and a standard deviation of 1.01633. On the other hand, the statement "increase in the built-up areas has reduced water infiltration" (ILULCC6) received

the lowest mean of 2.9429, with a standard deviation of 1.30646. The descriptive statistics for the impact of LULCC are summarized in Table 4.6.

Table 4.6: Descriptive Statistics for impact of LULCC

Code	Item	Mean		SD
		Stat	SE	Stat
ILULCC1	Almost all wetlands have dried up due to poor farming methods.	3.9857	.13573	1.13563
ILULCC2	Over-abstraction of water from the river reduces water quantity.	4.4429	.12147	1.01633
ILULCC3	Majority of farmers have cleared riparian vegetation for agriculture.	4.0571	.13480	1.12785
ILULCC4	Community water conflicts have resulted from the low quantity of the river flow due to abstraction	3.3429	.20133	1.68442
ILULCC5	There has been intensive erosion due to the degradation of the riparian vegetation	3.7143	.13052	1.09204
ILULCC6	An increase in the built-up areas has reduced water infiltration.	2.9429	.15615	1.30646
ILULCC7	Water pollution has resulted from use of farm chemicals and the washing of clothes in the river	3.4714	.14915	1.24786
ILULCC8	Illegal abstraction has resulted to drying up of tributaries	3.4857	.14637	1.22466

Source: Survey data (2018)

From the statistics, 73.6% of the respondents resonated with the items applied in measuring the impacts of LU/LCC. Descriptively, the item measuring the abstraction of water from the river and swamps had the highest mean, indicating a strong impact. All items used to assess the effect of land use/land cover change (LU/LCC) showed high mean values. The correlation analysis results suggested a significantly positive relationship between LU/LCC and watershed functions. This was also displayed in interviews. The key informants affirmed that there was overabstraction of water from the rivers and their tributaries, hence reducing water quantity in the watershed. This was connected to farming, population expansion, and the emergence of more factories in the watershed. One of the respondents reported the following;

“For the factories like tea and coffee factories we have conflicts because of over abstraction.” (IIR/L1-2/P.2)

Drawing from the document analysis, only 31% of abstractors have a legal permit, while the remaining 69% comprise abstractors without any legal document, and the majority of them are not even aware of the permit need (TUWRUA, 2018). There are more than 100 abstractors in the Tungu-Naka sub-catchment, done in all tributaries as well as the main river for domestic, irrigation, industrial, as well as underground pumping for institutional use. The majority of the abstractors are gravity pipelines, around 98% of the abstractors. Qualifying for possible over abstraction due to a lack of proper monitoring of the quantity of water abstracted and the responsible persons. As a result, there is a need for some form of regulation and monitoring because there is no cost per cubic metre associated with abstraction by gravity. From the Landsat images, it is also evident that increased human activities in the watershed have led to the destruction of water bodies in the sub-catchment, like wetlands and tributaries. This was evident during fieldwork, where the researcher came across so many dry springs and swamps with several farming activities within the vicinity.

The results are similar to (Nian et al., 2014) that found the over abstraction of surface water and over extraction of groundwater to have impacted harmfully on the natural environments, especially on water resources. The same research also found that because of abstraction, conflicts developed between the people living on the upper side of the basin and the lower side of the basin.

As a result of abstraction, water conflicts were reported by the two key informants to have occurred because of a shortage of water supply in some regions. Below are some of the responses from the interviews:

“There are conflict because of over abstraction of water from the river, abstraction is still there.” (I2R/L28/P.1)

“We have reduced water quality and quantity, this has created conflicts of water coz water is not enough for everybody to farm and other purposes.” (I1R/L37-38/P.1)

Furthermore, more than 75% of the respondents reported that clearance of vegetation had caused soil erosion and reduced water infiltration, thereby reducing water quantity in the river and tributaries. This concurs with (Hogan & Luzi, n.d ; Rwigi et al., 2024; Dinca et al., 2025) studies that revealed that the conversion of natural vegetation to farming land and built-up areas can abruptly interfere with evapotranspiration, and also soil permeability due to compaction of soil.

“Increase in the built-up area has a negative effect in the water resources in the watershed in that sub-catchment in that area like the streams are drying up and reduction in infiltration of water in the area hence reducing water recharge.” (I1R/L8-11/P.1)

“There has been reduced capacity of the soil to capture rain coz you see this land cover helps in holding water and it releases it pole pole (slowly by slowly).”(I1R/L33-43/P.1)

“Emergence of Chuka University has forced development of many hostels in the area, you know when we start having many concrete slaps, erosion is a must and the rate of infiltration also reduces.”(I2R/L22-24/P.2)

Planting of eucalyptus was also reported by 70% of the respondents to have triggered drying of the watershed, jointly with quarrying activities that were being practiced in the watershed. This finding was similar to that of the questionnaire, whereby 89.9% of the respondents

resonated with the statement that planting eucalyptus has resulted in the drying up of the watershed. This finding differs from the findings of a study conducted among small-scale farmers in Ethiopia, which reported higher productivity of croplands with eucalyptus as compared to the croplands with other trees (Zelege, Kassawmar, Tadesse, Teferi, Girma, Anteneh, Gelaw, Walsh, & O'Donnell, 2024). However, this finding was based on 1-year cross-sectional data.

“We have very big quarries along Tungu River. This is a challenge because they are drying up the tributaries that they drain their water in Tungu River.” (I2R/L5-7/P.2)

“The other challenge is planting of eucalyptus trees; they have been planted in all even in the wetland and river basin.” (I2R/L8-9/P.2)

From observation, erosion was observed as one of the effects of LULCC in Tungu-Naka sub-catchment where the researcher came across so many galleys because of erosion. It was concluded so because of heavy loads of soil that could be seen at the riparian zone emanating from the nearby land. Plate 4.1 below shows an eroded part of Naka sub-catchment.



Plate 4.1: Erosion on the riparian land of Tungu-Naka sub-catchment

Below is figure 4.7(a) and (b) showing discharge of Tungu River from year 1960 to 2018, though data for some years was missing.

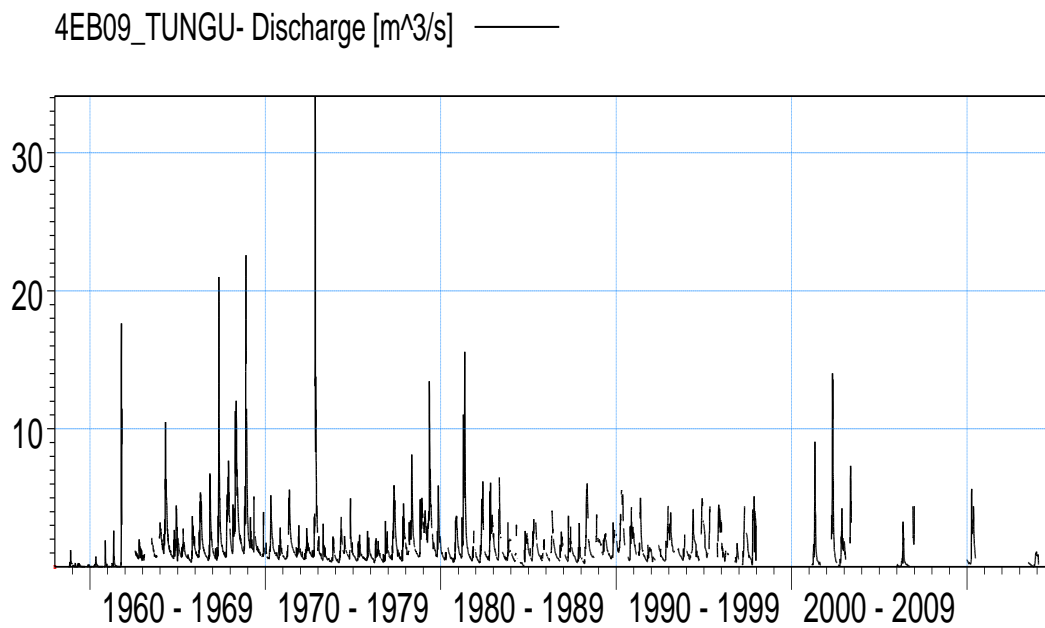


Figure 4.7(a) Tungu river average annual discharge

(Source: TUWRUA 2018)

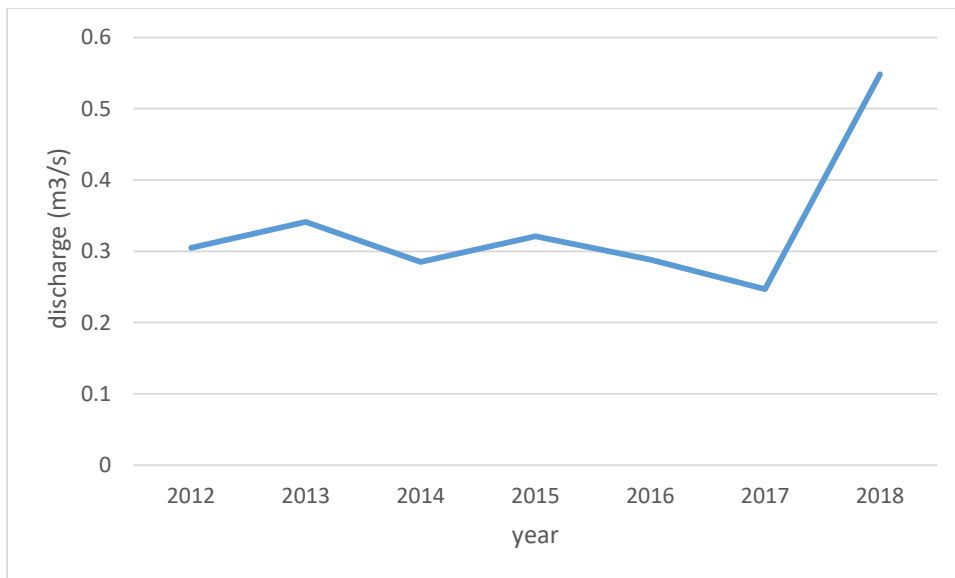


Fig 4.7 (b) Tungu river average annual discharge

(Source: TUWRUA 2018)

From the discharge data in Figure 4.7 (a) and (b), there has been rise and fall of discharge. In

2018, the discharge rate appears to be high compared to previous years though there was missing data for some months during the year, especially during the dry seasons, justifying the high discharge reported in the year. The lowest discharge was recorded in the year 2017 of 0.25 M³/s. Low discharge could be linked to deforestation and population increase that resulted to high demand for water and land for settlement as evident in the LU/LCC maps above. Moreover, the researcher found that there were three-gauge stations in the sub-catchment under study but only one located at the middle zone of the sub-catchment was operational. The rest were documented to exist in the WRMA documents but on the ground, they were not there. This therefore led to approximation of data in some months.

From the statistics, items used to measure impact of LU/LCC recorded a mean 73.6% meaning that LULCC impacts on the watershed function in the sub-catchment under the study. Water conflict took the intermediate stage because of a reduction in the quantity of water due to over abstraction. This could have been influenced by the expansion of population and the change in farming methods to the irrigation of fast-maturing crops. This in turn was found to influence watershed functions, including water quantity, infiltration, riparian vegetation, and river discharge. The findings agreed with the I=PAT theoretical framework that regional forces (population growth, agricultural growth, improvement in standards of living) influence LU/LCC (Ehrlich and Holdren, 1971).

In terms of the general application of the theory, the changes caused in one region by the above factors result in changes in other regions, hence explaining why the watershed is influenced by the changes taking place in different parts of the watershed. For instance, the conflicts between downstream and upstream populations because of over-abstraction that was found to be placed on the upper region of the sub-catchment.

4.6 Objective 4: Existing strategies

The descriptive statistics for the measures of central tendency and dispersion were calculated for the items assessing the existing strategies of objective four. The mean values of the items ranged from 2.4857 to 3.8857, while the standard deviations varied between 0.98897 and 1.44613.

The overall mean and standard deviation for the existing strategies were 3.0898 and 0.72361, respectively. The low standard deviation indicated minimal variability in the responses regarding the existing strategies. The mean standard error of 0.08649 reflected the reliability of the mean. The item "integrated watershed management and conservation is of much importance to me" (ES7) had the highest mean score of 3.8857 and a standard deviation of 1.25736. In contrast, the item "community education on watershed management is effective to many farmers" (ES4) received the lowest mean score of 2.4857 with a standard deviation of 0.98897. These results were presented in Table 4.7.

Table 4.7: Descriptive Statistics for Existing strategies

Code	Item	Mean		SD
		Stat	SE	Stat
ES1	I am aware of an organization that deals with watershed management and conservation in this area.	2.9000	.17285	1.44613
ES2	I have been given education plan on watershed management and conservation.	2.7143	.14409	1.20558
ES3	I have benefited from the management and conservation activities being practiced in the watershed.	2.7286	.14521	1.21490
ES4	Community education on watershed management is effective to many farmers.	2.4857	.11820	.98897
ES5	I do not find it difficult to release part of my land to be used for watershed management and conservation purpose.	3.3571	.14394	1.20429

ES6	I have been participating in planting of trees to protect the riparian zone.	3.5714	.13887	1.16185
ES7	Integrated watershed management and conservation is of much importance to me.	3.8857	.15028	1.25736

Source: Survey data (2018)

Descriptive statistics showed that there were some existing strategies for watershed management and conservation in the sub-catchment under study, though they are not effective. This is contrary to the results of (Mathenge et al., 2014) in Ngaciuma-Kinyaritha sub-catchment that revealed Community Water Management Systems (CWMSs) operating in the sub-catchment were doing so well in water resource management and farming water development, and ensuring water supply sustainability, hence scoring (62%) and (50%) respectively. From the same statistics, 52% of the respondents seemed not well sensitized to the importance of watershed management and conservation, while 5% were not sure. This was supported by the statement that community education was not effective in teaching about watershed management and conservation. This is as shown in Figure 4.8 below.

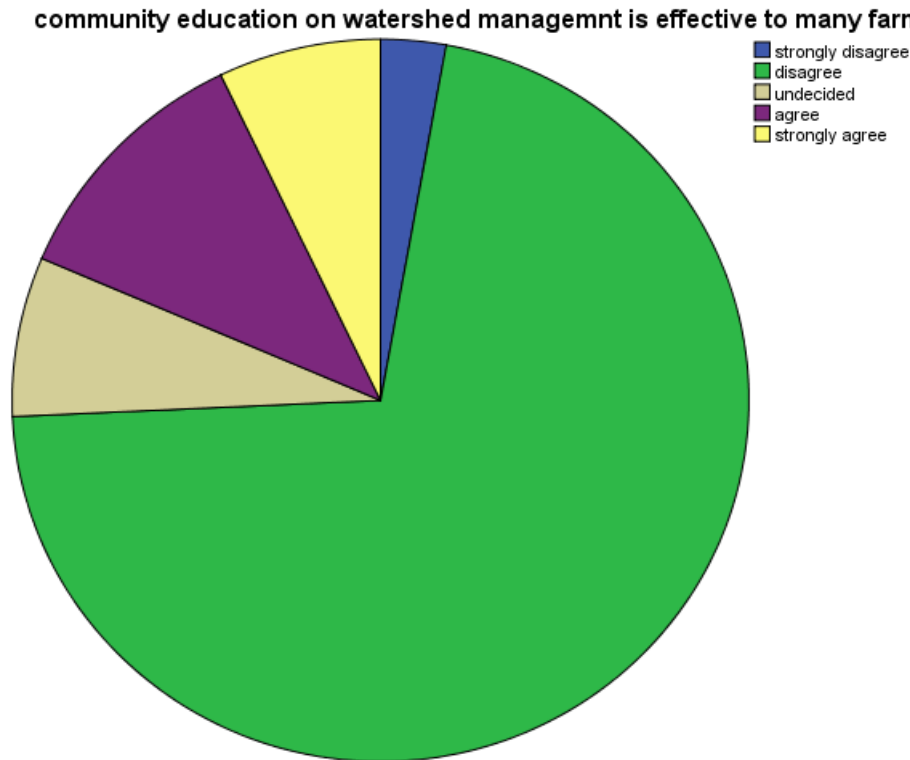


Figure 4.8: Response on existing strategies

Moreover, 32.8% of the respondents reported not being ready to release part of their land to be used in management and conservation work, while 67.2% did not have any challenge. This was distinct from the mean posted by the item. Statistically, the highest number of respondents demonstrated having participated in a tree planting exercise along the riparian zone, which was evident from the high mean posted by the item.

The quantitative findings were like the interview findings. 75% of the responses portrayed that the community members are being sensitized on the importance of riparian land and how to demarcate it by TUWRUA and WRMA, but some community members were cutting down the trees. This concurred with a study conducted in India that proposed the introduction of programs that build community adaptability through watershed restoration (Hale et al., 2014).

“We have started with Tungu sub catchment, we are helping them to sensitize riparian landowners to leave a minimum of 6 meters from the channel on both sides but then the process has not picked coz there is a lot of resistance.” (I1R/L25-26/P.1)

“As the TUWRUA we are trying to restore the glory of the river by planting trees along the riparian area, and also pegging riparian area so that we can dictate what should be planted along the riparian land.” (I2R/L11-12/P.1)

“Because of the size of the river, which is not a very big river, we demarcated 6 meters either side of the river and the tributaries we go up to 3 meters.” (I2R/L18-20/P.1)

Similarly, above 80% reported that their main existing strategy on watershed management and conservation in Tungu-Naka was planting of trees along the riparian land.

“The conservation that has been done with the sub-catchment is only planting of trees.” (I1R/L22-23/P.2)

“We have been planting vegetation along the riparian areas.” (I2R/L14/P.1)

“There is sensitization on conservation especially tree planting, so we sit together with community members, and they are sensitized on conservation.” (I1R/L12-13/P.2)

From the interview responses, as much as trees were planted, a percentage of community members (which was given) seemed not to support the program because they cut them, but TUWRUA was found to discourage the practice, by sensitizing some community members within the watershed to protect them (only in the upper part of the sub-catchment). This was in line with Lenton & Mulle (2012); Mwanguni et al., (2016) study that there should be capacity building for the population residing in the watershed, on the impacts of their activities on the watershed functions and how they can be controlled. There was a similar recommendation that

there is a need for an integrated approach to handle the challenges facing the watershed , from a research conducted in Bwathanaro watershed in Meru North on development of participatory watershed plan (Agwata, 2006).

“The trees that we have planted in the area have become the source of animal feed and harvesting of firewood, the trees belong to them not to RUA.” (I2R/L23-25/P.1)

“In achievements, RUA is trying by involving the various landowners and the users of the watershed so that they can take care of the trees.” (I1/L16-18/P.2)

“We are fighting especially cutting down of trees and also planting of eucalyptus trees along the river.” (I2R/L28-29/P.2)



Plate 4.2: Coffee, miraa and eucalyptus plantation on riparian land

Source: TUWRUA, 2018

Another form of capacity strengthening was training community members on alternative sources of livelihood, though it was reported not to have taken off well. Huang & Lo (2015), also suggested in their study that there should be regulation of the policies related to land use.

“What we have also been doing mostly is giving alternative livelihoods coz you see this work of conservation does not have economic benefits.” (IIR/L31-32/P.3)

Statistical findings revealed that 45.8% of the respondents were ignorant of conservation and management. Interview reports also revealed that sensitization has not been done on all parts of the sub-catchment, hence some community members still lack the knowledge on how to do it.

“Not all are receptive, some do not want to be involved in the process because they are still ignorant. RUA has not been able to go to all parts of the sub-catchment.” (IIR/L20-21/P.2)

“The young generation once the land is inherited to them, they cut all the trees without understanding why those trees were planted there.” (IIR/L22-23/P.3)

As much as there are some existing strategies on watershed management and conservation in Tungu-Naka sub-catchment, a majority were found not effective because of some hindrances like inadequate awareness among community members, lack of alternative source of livelihood, negative attitude towards conservation and management among community members, inadequate funds, minimal support from the county government, laxity and absence of clear records especially on abstraction. Some of the views were as follows;

“Formerly there was no serious measures and that is why there has been all these challenges, so there is nothing much that was being done.” (I2R/L35-36/P.2)

“We are trying to sensitize the abstractors; we don't have funds to do that work because it is very expensive. Even the abstractor's records are not available, there are no measures to curb the challenge of drying the wetlands and abstraction, it's now we are trying to come up with some.” (I2R/L1-3/P.3)

“The only problem we have, is land ownership especially when you talk of swamps, which should have been demarcated as public land, but almost all of them were demarcated as private, and these swamps have been dried up by the owners so that they can use the land.” (I2R/29-31/P.1)

“The county government has not supported as in any way.” (I2R/L16/P.2)

“Even the minister for environment in this county has not supported us in any way, we have been consulting them, but they do not come in in any way.” (I2R/L18-19/P.2)

According to TUWRUA abstraction report (2018), 69% of the abstractors lacked the required legal documents. Some completed farming projects were found to have only authorizations which were already expired, others had permits that had also expired, and in many cases, these documents were misplaced and were not traceable. Moreover, the guidelines set for farming in the sub-catchment were not followed due to the absence penalties for the same.

Furthermore, the study reported that there were various factors influencing watershed management. 60% of the respondents were found not to be aware of the existing strategies in management and conservation of the watershed. This could have contributed to the encroachment of riparian land and also over-abstraction of water. As a result, there need for capacity enhancement through training and involvement of community members on proper methods of watershed management and conservation. Nevertheless, community members require sensitization on proper communication channels in case of an incident within the watershed that needs to be reported to the service providers by the community members. This could be because of a lack of motivation among the leaders of TUWRUA, as depicted in the verbatim, where one of the respondents stated that they do not get any support from the county government.

As a result, not all community members in the sub-catchment were adequately sensitized on watershed management and conservation. Only 49.6% of the respondents agreed that the community education efforts on these topics were effective.

This was also reflected in the interview responses that TUWRUA had not succeeded to train all the community members in the sub-catchment on their role in managing the watershed. From the above findings, degradation and encroachment could have been contributed by little awareness among community members on best strategies for watershed management and conservation as well lack of involvement in formulating these strategies by WRMA. From the fieldwork management and conservation efforts were only seen in the upper and the middle zone leaving behind the lower zone of the sub-catchment. Little efforts were reported on watershed management and conservation. However, TUWRUA was reported to have made baby steps on the conservation of the sub-catchment by sensitizing its officials on alternative sources of fuel, for example use of energy-saving jikos (stooves). However, this strategy had not been transmitted to the community water users, who happen to be the greatest consumers of the sub-catchment resources. This led to the question of how many watershed dwellers had this knowledge? This means that there is useful information that is geared towards sustainable development, but has not been transmitted holistically to the beneficiaries. If campaigns on integrated watershed management can be conducted throughout the sub-catchment, Tungu-Naka would be saved from degradation.

4.7 Watershed functions

The descriptive statistics for the six items assessing watershed functions were calculated, with mean values ranging from 2.6857 to 3.0429 and standard deviations between 1.25966 and 1.37231. The overall mean for the watershed function items was 2.8833. Given the 5-point Likert scale used in the study, this suggests that watershed functions play a role in determining

the importance of a sub-catchment to a particular community. The standard deviation, which reflects the spread of the scores, had an average value of 0.75353, indicating a moderate dispersion of values for watershed functions as a variable. Additionally, the small standard errors implied that the mean values, including the general mean, were reliable. These descriptive statistics were presented in Table 4.8.

Table 4.8: Descriptive Statistics for watershed functions

Code	Item	Mean		SD
		Stat	SE	Stat
WF1	Riparian vegetation facilitates water infiltration.	2.9143	.15056	1.25966
WF2	Riparian vegetation protects the river from erosion	3.0286	.16402	1.37231
WF3	Tungu river tributaries contribute to water quantity in the river	3.0429	.16334	1.36664
WF4	wetlands within the watershed contribute to river recharge	2.7286	.15353	1.28448
WF5	the sub-catchment provides water for domestic purposes	2.6857	.15165	1.26883
WF6	trees along the sub-catchment facilitates the circulation of water into the river	2.8000	.15841	1.32534

Source: Survey data (2018)

The overall mean on watershed functions was 2.88 (56%). This meant that the Tungu-Naka sub-catchment was not able to perform all its functions effectively because of some factors discussed under the factors leading to LU/LCC. According to statistics, the Tungu-Naka sub-catchment was found to play a very significant role in the community living around, but it was found struggling to regenerate due to the absence of proper management and conservation measures. From the correlation analysis below in table 4.11, the watershed function was found to have a significant relationship with the impact of LU/LCC. This means that watershed

functions retrogresses as LU/LCC increases. This was evident from the river discharge data from 2012 to June 2018.

4.8 Test of Statistical Assumptions

The data was tested to determine whether the assumptions of ordinary least square (OLS) are met. These are the factors that need to be considered before conducting any statistical analysis. If the data does not meet the threshold, other types of analysis should be considered.

4.8.1 Test of Normality

Most inferential statistical methods require the assumption of normality (Field, 2009). Normal data is typically characterized by symmetry and a bell-shaped distribution, with the highest frequency of scores occurring in the center and progressively smaller frequencies at the extremes. Normality can be assessed through the values of skewness and kurtosis. Skewness refers to the symmetry of the distribution, while kurtosis measures the degree of peakedness or flatness of the data (Tabachnick & Fidell, 2007). In this study, the skewness values ranged from -0.070 to 0.057, and the kurtosis values ranged from -0.712 to 0.322. According to Hair (2010), values between -1 and +1 indicate normality. Since all skewness and kurtosis values fell within this range, it was concluded that the data distribution for the variables was normal. The summary of these results is presented in Table 4.9.

Table 4.9: Normality Test Results

	Mean	Std.	Skewness		Kurtosis	
	Statistic	Deviation	Statistic	Std. Error	Statistic	Std. Error
factors leading to LU/LCC	3.8646	.66597	-.951	.287	.044	.566
impacts of LULCC	3.6804	.74868	-.807	.287	.322	.566
existing strategies	3.0898	.72361	.057	.287	-.192	.566
watershed functions	2.8833	.75353	-.070	.287	-.712	.566

Source: Survey data (2018)

4.9 Correlation Analysis of Study Variables

A correlation analysis was performed to examine the relationship between watershed functions and the variables associated with objectives 2, 3, and 4 (Wong & Hiew, 2005). The results of the analysis are presented in Table 4.10. Some variable pairs exhibited significant correlations at the 0.01 level, indicating that the hypothesized relationships were statistically significant ($p < 0.01$). A significant positive relationship was found between watershed functions and the impact of LU/LCC ($r = 0.458$, $p < 0.01$). However, the relationship between watershed functions, factors influencing LU/LCC, and existing strategies was not statistically significant and therefore did not show any asterisks. The study aimed to examine the effect of Land Use/Land Cover (LU/LCC) on watershed functions, focusing on how the independent variable (LU/LCC influence) affects the dependent variable (watershed functions). The null hypothesis (H01) proposed that there is no significant relationship between the influence of LU/LCC and watershed functions. The correlation analysis revealed a positive relationship between the impact of LU/LCC and watershed functions. Table 4.11 below presents the results of the correlation analysis.

Table 4.11: Correlation Coefficients

		factors leading to LU/LCC	impacts of LULCC	existing strategies	watershed functions
factors leading to LU/LCC	Pearson Correlation	1	.488**	.185	.078
	Sig. (2-tailed)		.000	.125	.519
	N	238	238	238	238
impacts of LULCC	Pearson Correlation	.479**	1	.220	.458
	Sig. (2-tailed)	.000		.068	.962
	N	238	238	238	238
existing strategies	Pearson Correlation	.185	.220	1	.004
	Sig. (2-tailed)	.125	.068		.974
	N	238	238	238	238

watershed functions	Sig. (2-tailed)	.078	.006	.004	1
	N	.519	.962	.974	
	Pearson				
	Correlation				
	Sig. (2-tailed)	238	238	238	238
	N				

**. Correlation is significant at the 0.01 level (2-tailed).

Source: survey data (2018)

Based on the results above, the null hypothesis was rejected, and the alternative hypothesis was accepted, indicating that there is a significant statistical relationship between land use/cover change and watershed functions in the Tungu-Naka River sub-catchment.

Table 4.12: Summary of the Hypotheses Tests Results

Statement	Results
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H₀₁ LU/LCC has a statistically significant relationship with watershed functions.

Rejected H₀

From the above data illustration, the null hypothesis (H₀) stating that there is no statistically significant relationship between Land Use/Land Cover Change (LU/LCC) and watershed functions was rejected, and the alternative hypothesis was accepted. This indicated a statistically significant relationship between LU/LCC and watershed functions. The findings reveal that LU/LCC influences watershed functions negatively. Therefore, it is essential to implement sustainable resource utilization practices to mitigate the negative effects of LU/LCC.

Summary:

This chapter presented the results derived from both quantitative and qualitative data collected for the study. These data sets offered valuable insights into the influence of Land Use/Land Cover Change (LU/LCC) on watershed functions in the sub-catchment area under

investigation. The chapter outlines methods used for data collection and generation to provide clarity and direction for future readers interested in understanding the study's findings. The results are organized based on Landsat images that track LU/LCC trends over the study period, respondents' perspectives on the impacts of LU/LCC on watershed functions, the factors influencing LU/LCC, and the measures implemented to improve watershed management and conservation.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter entails the summary of findings, conclusions, recommendations, and areas for further study according to the outcomes realized in the study. Below are subsections of this chapter.

5.2 Summary of research findings

5.2.1 Objective 1: To analyze the trends in land use/ land cover in the Tungu-Naka watershed between 2002 and 2018.

Wetland areas and forest areas experienced the greatest change among the classes identified. The area under the wetland was 0.450 hectares in 2002, but this gradually reduced to a negligible size, calculated as 0 hectares by 2018. Percentage changes included 46.667% (2002–2006) and 20.833% (2006–2012). By the end of the 2012–2018 period, the area was so negligible that it resulted in a 0% change, as it could not be noticed using the employed Landsat images.

Forest cover showed a positive percentage change over the entire study period (2002 to 2018). Specific percentage changes for forest cover were 6.276% (2002–2006), 1.517% (2006–2012), and 1.514% (2012–2018). The area under agriculture did not have a consistent change. In 2002, the area was 16339.032 hectares. It was reduced to 15835.406 hectares in 2006. It then increased to 15925.004 hectares in 2012 and 16273.917 hectares in 2018. Percentage changes for agriculture were an initial positive change of 3.082% (2002–2006), followed by negative changes of -0.566% (2006–2012) and -2.191% (2012–2018).

Grassland recorded initial negative percentage changes, specifically -3.778% (2002–2006) and -6.652% (2006–2012). However, between 2012 and 2018, there was a positive change of 4.999%. This positive shift may have been contributed to by a reduction in bare land and forest area.

Other changes observed were partly associated with population growth in the sub-catchment, which is evident from population statistics provided by KNBS. Additionally, the study noted a consistent negative percentage change on three comparison levels, with specific values of 16.770% (2002–2006), 116.368% (2006–2012), and -13.535% (2012–2018)

5.2.2 Objective 2: To identify and evaluate the driving factors of land use and land cover change in the Tungu-Naka sub-catchment between 2002-2018.

LU/LCC was found to have been caused by various drivers. These factors include population growth, high demand for water, modern farming technology, demand for agricultural land expansion of built-up area, and ignorance among sub-catchment dwellers. Population growth in the sub-catchment under study was found to have greatly contributed to LU/LCC due to demand for settlement land and food, hence intensive farming that was reported to have caused strain on the available resources. High water demand was another factor that enhanced land use change in the sub-catchment, resulting in over-abstraction.

Correlation analysis showed that the relationship between watershed functions and factors influencing LU/CCC was not statistically significant, hence did not have any asterisks.

5.2.3 Objective 3: To assess the impacts of land use and land cover change on the hydrological and ecological functions of the Tungu-Naka sub-catchment.

Expansion of the built-up area due to urbanization was found to have resulted in a reduction in water quantity in the river caused by the high demand, as well as a reduction in infiltration.

Conversely, wetlands in the sub-catchment were found to have increasingly dried up due to human encroachment driven by the demand for additional agricultural land. In addition, the widespread planting of eucalyptus trees, commonly used for construction and firewood, further contributed to the depletion of wetlands and swamps. Moreover, expansion of settlements resulted in the cutting of trees to create space for settlement, hence interfering with evapotranspiration and infiltration in the watershed. It has also led to an expansion of the area covered by bare land in the sub-catchment, hence activating more erosion, especially on the riparian land. Irrigation along the riparian land resulted in high demand for water, leading to over-abstraction hence reducing river discharge and water quantity in the sub-catchment and drying of the wetlands. This was found to have caused conflicts among the communities living in the sub-catchment due to inadequate water flow to the communities living in the lower side.

The items used to measure the effects of land use/land cover (LU/LCC) change were found to be statistically significant at the 0.01 level, indicating that the hypothesized relationships were significant with $p < 0.01$. Correlation analysis revealed a positive and significant relationship between watershed functions and the effect of LU/LCC ($r = 0.458$, $p < 0.01$).

As a result, the null hypothesis, which suggested no significant relationship between land use/cover change and watershed functions in the Tungu-Naka sub-catchment, was rejected. In its place, the alternative hypothesis was accepted, confirming a significant relationship between LU/LCC and watershed functions in the Tungu-Naka River sub-catchment.

5.2.4 Objective 4: To evaluate existing watershed management strategies in the Tungu-Naka sub-catchment and assess their effectiveness.

TUWRUA was found to have attempted management and conservation of the watershed but with less than 50% success. The main form of conservation found to be practiced in the

watershed is pegging the riparian land and planting of trees along the riparian land, especially on the upper side of the watershed. However, this was found to have achieved little because a majority of community members did not support the exercise, hence cutting down trees, practicing irrigation along the riparian land, and planting eucalyptus trees on the wetland and along the river. An alternative source of livelihood was another strategy found to have been adopted in watershed management and conservation, with minimal success achieved. The majority of farmers were found to feed their goats from the trees planted on the riparian land, as they felt that they were not getting any direct benefit from tree planting since its long term, hence losing hope. Inadequate funding, cultural values and lack of support (county) were found as the challenges to its effectiveness of management and conservation.

Another factor that was found to hinder the effectiveness of watershed management and conservation in the sub-catchment was ignorance among some community members. TUWRUA together with WRMA admitted that they have not been able to sensitize all community members in the sub-catchment especially those that own riparian land. Furthermore, data on legal abstractors and the amount of water expected be abstracted by each was not available hence encouraging over abstraction and also illegal abstractors.

Furthermore, it was found that there are no set measures on the action to be taken on those found destroying riparian vegetation and practicing over-abstraction of water or even drying up wetlands for farming.

Consequently, individual ownership of wetlands emerged as a major challenge to the effectiveness of conservation strategies. Most wetlands were privately owned, leading to their conversion for irrigation and other land uses, which contributed to their degradation.

Furthermore, the correlation analysis revealed no statistically significant relationship between the existing strategies and watershed functions, as indicated by the absence of significance markers.

Consequently, individual wetland ownership was found to be another challenge to the effectiveness of the strategies since the majority of the wetlands were found to be owned by individual community members, hence drying them up for farming and other land uses.

In correlation analysis, the relationship between existing strategies and watershed functions was found not statistically significant, hence it did not have asterisks.

5.3 Conclusions

The research found that there were main LU/LCC in Tungu-Naka sub-catchments within the period under study, which were mainly linked to the expansion of settlement and agriculture.

The results also revealed that more LU/LCC was likely to take place with more land being converted to built-up areas and agriculture, threatening water sources in the future. If sustainable watershed conservation and management measures are not considered, there will be continuous degradation of the watershed, hindering the achievement of Sustainable Development Goals (SDGs) 15 and 6 and Vision 2030.

Understanding how LU/LCC influences watershed functions in the sub-catchment will help developers come up with policies and suggestions that reduce the undesired impacts of future LU/LCC and also focus on sustainable development. The watershed functions in the sub-catchment are currently under pressure due to rapid LU/LCC in the Tungu-Naka sub-catchment.

The influence of LULCC is largely negative. For instance, increased water demand driven by expanding settlements has resulted in the over-abstraction of water from rivers and wetlands.

Trees play a critical role in regulating the evapotranspiration cycle, enhancing groundwater recharge, and facilitating infiltration and percolation. However, the clearing of riparian vegetation accelerates riverbank erosion and increases surface runoff during the rainy season, ultimately reducing water recharge during the dry season.

The existence of TUWRUA was found not to be enough to guarantee successful watershed management and conservation in the sub-catchment under study. The county government department of environment and natural resources was reported not to have supported TUWRUA in ensuring successful integrated watershed management. Frequent monitoring of LU/LCC in the sub-catchment can be done using modern tools like remote sensing and Geographic Information System (GIS) to ensure sustainable utilization of resources in the watershed.

5.4 Recommendations

5.4.1 Land use/land cover trend from 2002 to 2018

Modern technology should be applied by the national government together with Tharaka/Nithi County government in monitoring and controlling land use and land cover change in the sub-catchment to avoid unplanned development that may cause negative impact on the sub-catchment. GIS and remote sensing technology can be used in monitoring and projecting future changes in LU/LCC.

5.4.2 Causes and impacts of LU/LCC

The Ministry of Environment and Natural Resources should lead campaigns for sensitizing the public on the importance of trees in relation to protecting the watersheds, not only the watershed under study, but nationwide. There should also be controlled and regulated abstraction of water from the river to encourage equal sharing of the resource between communities living on the upper side of the sub-catchment and those at the lower side. The government, through WRUA should protect the wetlands from destruction by the public. This can be achieved through the introduction of penalties for any individual reported to have encroached.

5.4.3 Management and conservation of the watershed

Recent literature shows a complex relationship between anthropogenic activities and environmental activities. Understanding the changes is important when planning for viable land management procedures and in responding to negative effects on watershed functions. There should be continued research and technological innovations to feed different water policies and amend the practices of watershed management globally.

The county government, through the Minister for Environment, should support TUWRUA in sensitizing the community on watershed management and conservation. Frequent and intensive sensitization should be conducted among community members in the sub-catchment on integrated watershed management and conservation. Moreover, apart from planting trees, TUWRUA, with the help of WRMA, should come up with participatory watershed management and conservation strategies, and this can only be achieved through embracing the blend between indigenous knowledge and technology, and innovativeness among community members. Finally, serious measures should be put in place for those found practicing illegal abstraction of water, and also clear records of legal abstractors and the amount to be abstracted should be put in place. There is a need to increase the number of monitored gauge stations for effective watershed management. The findings revealed that only three gauge stations exist in the area, and just one of them is currently operational. Consequently, there is a need for co-creation between the duty bearers (government), service providers, and the beneficiaries (community members) on what best watershed conservation measures work for the sub-catchment. This practice will ensure buy-in and ownership of the identified measures by the community members.

5.5 Areas for further research

A similar study can be replicated in a sub-catchment located in a different climatic zone and with distinct cultural practices among the local community. Other areas include;

- 1) Use of more images in evaluating the trend of land use/ cover change.
- 2) Analysis of water quality in the Tungu-Naka sub-catchment in relation to farming and the development of factories.
- 3) Evaluating the influence of land use/ cover change on underground water in the sub-catchment.
- 4) Geomorphic effect on the river channel and bank as a result of surface runoff in the sub-catchment.
- 5) Influence of climatic factors on watershed functions in Tungu-Naka sub-catchment.

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APPENDICES

APPENDIX I: UNIVERSITY INTRODUCTION LETTER FOR NACOSTI PERMIT



**KENYATTA UNIVERSITY
GRADUATE SCHOOL**

E-mail: dean-graduate@ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 57530

Website: www.ku.ac.ke

Internal Memo

FROM: Dean, Graduate School

DATE: 14th February, 2018

TO: Njage K. Rose
C/o Geography Dept.

REF: C50/CE/25604/14

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

=====

This is to inform you that Graduate School Board, at its meeting of 13th February, 2018, approved your Research Proposal for the M.A. Degree Entitled, "Influence of Landuse and Landcover Change on Watershed Functions in Tungu River Sub-Catchment in Tharaka-Nithi County, Kenya".

You may now proceed with data collection, subject to clearance with the Director General, National Commission for Science, Technology and Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking forms per semester. The form has been developed to replace the progress report forms. The supervision Tracking Forms are available at the University's website under Graduate School webpage downloads.

Thank you.

JULIA GITU
FOR: DEAN, GRADUATE SCHOOL

c.c. Chairman, Department of Geography

Supervisors:

1. Prof. Joy Obando
C/o Department of Geography
Kenyatta University
2. Dr. Shadrack Murimi
C/o Department of Geography
Kenyatta University

APPENDIX II: NACOSTI PERMIT



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/18/57604/21668**

Date: **10th April, 2018**

Rose Kanana Njage
Kenyatta University
P.O. Box 43844-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on *“Influence of land use and land cover change on watershed functions in Tungu River Sub Catchment in Tharaka Nithi County, Kenya,”* I am pleased to inform you that you have been authorized to undertake research in **Tharaka Nithi County** for the period ending **9th April, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Tharaka Nithi County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Tharaka Nithi County.

The County Director of Education
Tharaka Nithi County

APPENDIX II: NACOSTI CLEARANCE CERTIFICATE

THIS IS TO CERTIFY THAT:
MS. ROSE KANANA NJAGE
of KENYATTA UNIVERSITY, 0-80100
Mombasa, has been permitted to
conduct research in *Tharaka-Nithi*
County

on the topic: **INFLUENCE OF LAND USE
AND LAND COVER CHANGE ON
WATERSHED FUNCTIONS IN TUNGU
RIVER SUB CATCHMENT IN THARAKA
NITHI COUNTY, KENYA**

for the period ending:
9th April, 2019



.....
Applicant's
Signature

Permit No : NACOSTI/P/18/57604/21668
Date Of Issue : 10th April, 2018
Fee Received : Ksh 1000



.....
Director General
National Commission for Science,
Technology & Innovation

APPENDIX IV: QUESTIONNAIRE FOR HOUSEHOLDS

Njage K. Rose

Department Geography

Kenyatta University

Date:

Dear Respondent,

My name is Rose a postgraduate student from Kenyatta University currently understanding Masters of Arts Degree Geography (Geomorphology). My research topic is on influence of Land Use, Land Cover Change on watershed functions in Tungu-Naka watershed. I'm requesting you to cooperate with me in filling in this questionnaire. Your answers will be held confidentially, just for academic purpose. Do not write your name on the questionnaire.

Thank you in advance

Questionnaire number

PART A: Individual Details

Gender: Male Female

Age: Below 24 25-34

35-44 45-54

55-64 Above 65

PART B: Factors leading to LU/LCC

Read each of the following statement carefully and indicate using a tick, the extent to which you agree or disagree with the following statement. Use Strongly Agree(SA) =5, Agree (A)=4, Undecided (U)=3, Disagree (D)=2, and Strongly Disagree (SD)=1.

NO	ITEM	SA	A	U	D	SD
1.	High demand for food has intensified small scale irrigation in the watershed.					
2.	Population growth in the watershed has led to clearing of riparian vegetation to create space for agriculture and settlement.					
3.	Advancing technology has encouraged farming of faster maturing crops like tomatoes and kales through irrigation.					
4.	Planting of eucalyptus and high demand for farming land has highly contributed to drying of Wetlands in the watershed.					

5.	Majority of the watershed residents are ignorant of sustainable utilization of the watershed.					
6.	Ready market for timber has led to some poor families cutting down trees to earn a living.					
7.	Some parts of the watershed are bare due to high demand of charcoal and firewood.					
8.	Low crop output from rain fed agriculture has made us shift to irrigation.					

PART B: Impact of Land Use /Cover change

NO	ITEM	SA	A	U	D	SD
1.	Almost all wetlands have dried up in the watershed due to poor farming methods.					
2.	There is over abstraction of water from the river hence reducing water quantity.					
3.	Majority of farmers have cleared the vegetation next to the river to create more land for agriculture.					
4.	Community water conflicts have resulted from low quantity of the river flow.					
5.	There has been intensive erosion in the watershed due to degradation of the riparian vegetation and trees to create agriculture and settlement land.					
6.	Increase in the built up areas has reduced water penetration to the soil.					
7.	water pollution has resulted from use of farm chemicals and washing of clothes in the river					
8.	Illegal abstraction has resulted to drying up of tributaries					

PART C: Existing strategies

NO	ITEM	SA	A	U	D	SD
1.	I am aware of any organization that deals with watershed management and conservation in this area.					
2.	I have been given any community/individual education plan on watershed management and conservation.					
3.	I have benefited in any way from the management and conservation activities being practiced in the watershed.					
4.	Community education on watershed management is effective to many farmers.					

5.	I do not find it difficult to release part of my land to be used for watershed management and conservation purpose.					
6	i have been participating in planting of trees to protect the riparian zone					
7.	Integrated watershed management and conservation is of importance to me.					

PART D: WATERSHED FUNCTIONS

NO	ITEM	SA	A	U	D	SD
1	Riparian vegetation facilitates water infiltration.					
2	Riparian vegetation protects the river from erosion					
3	Tungu river tributaries contribute to water quantity in the river					
4	Wetlands within the watershed contribute to river recharge					
5	The sub-catchment provides water for domestic purposes					
6	Trees along the sub-catchment facilitates the circulation of water into the river					

APPENDIX V: INTERVIEW SCHEDULE FOR KEY INFORMANT

Respondent number ----- Date -----

Department -----

Factors leading to landuse/cover change

1. Briefly explain some of the changes that have taken place?
2. What are some of the factors resulting to the change?

Impacts of Land use/cover change

1. In your own opinion, does the landuse/cover change has any impact on the watershed?

Conservation and management measures

2. Is there any measures put in place to ensure watershed management and conservation?
3. How do you rate the achievement of integrated watershed management and conservation in Tungu watershed?
4. How is the community involved in management and conservation of the watershed?
5. How often is the evaluation done on implementation of the measures put in place?
6. Is there any challenges faced in the implementation of conservation and management measures?

APPENDIX VI: RESPONDENTS CONSENT

My name is Rose Kanana Njage. I am a Master student from Kenyatta University, carrying out a study on influence of Land Use, Land Cover Change on watershed functions in Tungu watershed. The information given will be used for academic purpose only.

Procedures to be followed

Participation in this study will require that I ask you some questions and record the responses from you in a questionnaire. I may also audio record your responses to help me transcribe later for data analysis. I may have to take videos and photographs of your homes and farms.

Kindly note that involvement in this study is voluntary. You have the right to refuse getting involved in this study. Please remember that refusing to be involved in the study will not have any consequence whatsoever. You can ask the questions about the study at any time. You may reject to answer any questions, and you can stop an interview at any time.

Discomforts and risks

Questions about social aspects, sometimes touching on personal life or duties are some of the questions to be asked, which may make you a little uncomfortable. If you so wish; you can refuse to answer some of these questions. Furthermore, you can stop the interview at any period.

Benefits

Your participation in this study will help us to learn how land use/ landcover have influenced our environment particularly Tungu watershed. Recall that Tungu watershed is very important and that it provides many resources to you inhabitants and if not well managed, the inhabitants will be much affected especially on provision of water and farming.

Confidentiality

The interviews will be conducted in the households and key informants will be in their respective offices. Your name will not be recorded on the interview response. The questionnaire will be kept in a locked cabinet for safety. Everything will be kept private.

Contact information

If you have any questions, you may contact Prof. Joy Obando 0722 966134 or the Kenyatta University Ethical Review Committee Secretariat on kuerc@ku.ac.ke.

Participant’s statement

The above information regarding my participation in the study is clear to me. My participation in this study is entirely voluntary. I understand that the information I will provide will be kept in private and that I can leave the study at any time.

Name of participant **Signature or thumbprint**

Date.....

Investigator’s statement

I, the undersigned, have explained to the volunteer in a language she/he understands, the procedures to be followed in the study and the risks and benefits involved.

Name of interviewer.....

Signature.....Date

APPENDIX VII: INTERVIEW 1 (I1)

I: What has been the trend of LU/LC in Tungu river sub-catchment?

R: I'm not in a position to answer that, we have group or sub region who can help you there.

I: How does LU/LCC impact on the watershed?

R: We are aware that land cover are mostly natural is very important in enabling water to percolate on the ground, so when we clear trees and other natural vegetative cover then we are reducing then capacity of the soil to absorb water hence ensuring we have enough water in the springs and also ground water recharge, and so increase in the built-up area has a negative effect in the water resources in the watershed in that sub-catchment in that area like the streams are drying up and reduction in infiltration of water in the area hence reducing water recharge. So clearance of trees clearance of vegetative cover has a negative impact in the sub catchment in that area. But if there are efforts to maybe improve or reinforce on what is available and improve the land cover, then we will see a positive change, yea. We will see an improvement in the water availability and also water resources in terms of availability and quantity in the sub-catchment in general.

I: Is there any encroachment of the riparian zone?

R: Yes definitely. There is a lot of encroachment. You find for such areas like chuka to Tungu, most of encroachment is as a result of farming unlike in the town where you get much of encroachment is as a result of built up areas. People are farming all the way to river system, up to the riparian land and this has a negative impact to because we will see if they are using any farm inputs or pesticides, then will have a negative effect on water resources. One being soil erosion, two being pollution through soil erosion due to turbidity coz the waste is being washed down the river, and so it reduces the carrying capacity of the river channel.

R: But if we have some interventions, like what we have started with Tungu sub catchment, we are helping them to sensitize riparian land owners to leave a minimum of 6 meters from the channel on both sides but then the process has not picked coz there is a lot of resistance.

I: What about water quantity in terms of land use?

R: Eee.....definitely we have negativeDepends, in terms of these negative effects we have talked about like clearance of vegetation, overgrazing, construction of property and buildings, any human activity that Is negative, then will see degradation, both in quality and quantity. There has been reduced capacity of the soil to capture rain coz you see this land cover helps in holding water and it releases it pole pole, but when don't have it then we have water rushing in the streams very fast which cannot be withheld, water does not have enough time to infiltrate and so releasing the natural

way it was designed to do. So if we have a lot of open space, rain will come and go, therefore we have reduced water quality and quantity, this has created conflicts of water coz water is not enough for everybody to farm and other purposes. For the factories like tea and coffee factories we have conflicts because of over abstraction.

I: Is there any measures put in place to ensure watershed management and conservation?

R: Yea. For Tungu specifically right now we have supported them in the last financial year, to carry out conservation measures, by upper Tana natural resources management program and I think they have 4 nurseries, which they use for catchment watershed conservation, selling of trees. So the RUA has tried to do the catchment management.

I: Has it been effective?

R: Mmmmh.....i can say there is progress towards the improvement of the same, because mmm.... Usually they involve riparian land owners' coz RUA does not own any land. There is sensitization on conservation especially tree planting, so we sit together with community members and they are sensitized on conservation. So that those who have accepted are able to plant trees and take care of them within the riparian land.

R: So in terms of measures, yes we are doing tree planting. They have submitted a proposal to upper Tana, they want to do an enhancement of the nurseries they have. In achievements, RUA is trying by involving the various landowners and the users of the watershed so that they can take care of the trees,

I: Are all community members receptive?

R: Not all are receptive, some do not want to be involved in the process because they are still ignorant. RUA has not been able to go to all parts of the sub-catchment but where they have tried the community is a bit receptive in IWM. The conservation that has been done with the sub-catchment is only planting of trees, we have not done terracing yet. Yea. We do actual planting, and then monitoring of what has been done to evaluate the survival rates.

I: How often is the evaluation done on the implementation measures put in place?

R: Aah! For example the one they have done this year, we have been able to do field appraisal, we did field appraisal for them to establish where they wanted to carry out interventions are vulnerable areas. Then after we did that they were funded. After funding, there is monitoring, there are different levels of monitoring, we all it monitoring and evaluation. We do evaluation once a year but we have not been very keen, we are now trying.

I: So are you there to support the community throughout or after some time you will leave them to continue with program?

R: We are there to support them throughout, as I said earlier, the RUAs are anchored in the law, water act, and as they in the water act, they are under WRMA so in their life time, as much as they will be supported by different financiers, to carry out work, for technical support they will come back to us (water resource authority). We can say we are mother support to RUA.

I: Have you incorporated other leaders in the community?

R: Yes. Usually in our work, for us to ensure ownership, we have to involve them first of all from the chiefs. We can't do even these riparian protection we can't do it with RUAs only. Even some of these RUAs are leaders in their own making. And as we do that it is actually a requirement they must incorporate the already existing leadership locally. It is almost a government entity that's why. We even go further and involve ward administrators.

I Do you have gauge stations in that area?

R: Yes wee.... Have gauge stations in Tungu? I'm not very sure.

I: Any challenges faced in implementation of management and conservation measures?

R: Mmmh.... Yea. I think it's because one, conservation does not have any economic benefit and people want money, also conservation is a long term thing that the results will not be seen immediately. So sometimes you may conserve the area and you have agreed with the land owner riparian land owner that they will take care of the trees, but people can be a bait tactful and come up and uproot all those trees. Like for example in that sub- catchment there was some efforts which had been done previously by another donor MKEP, and the trees were doing very well. Recently somebody came and bought the land for investment, for settlement, without really knowing the importance of those trees what those trees were meant for, so we can say issues of land tenure, changing land ownership. If somebody want to change the use of land without understanding why those trees were planted and cut them all. Also generation change where the young generation once the land is inherited to them they cut all the trees without understanding why those trees were planted there.

I: What about the community members? Are they all willing to participate in the program?

R: They are those who do not buy the idea and they have other plans of utilizing the land. With continuous sensitization they can. There should be much sensitization. We put some money for planning and sensitization.

I: You don't give them any economic benefit after the participation as a form of enticement?

R: Okay has minimal what we have also been doing mostly is giving alternative livelihoods coz you see this work of conservation does not have economic benefits, if they know the benefits of conservation, they pick up and participate. We have introduced something new for alternative livelihoods as a source of earning income like we give you goats instead of farming along riparian zone.

I: Now that my research is for the past 15 years, coz you are talking about what was done last year, is there anything that was being done before apart from that?

R: Maybe we can say that water resource management issues were not being taken in seriously. Again the issue of population has a negative impact on the sub catchment because there is an increase in the built-up areas especially the coming up of Chuka University and also the establishment of county government. This has also led to the growth in population within the sub catchment hence more pressure on the watershed. The urban area within the region is growing at a very high rate.

INTERVIEW 2 (I 2)

R: Let me give you the history of Tungu River.

R: Tungu River traverses from Mount Kenya forest towards Tharaka. With time, and after demarcation, this land cover was cleared. Totally cleared because during the demarcation, it was being done up to the middle of the river. So ownership of land now became a problem because owners of the land claimed that their land is going all the way to the river. So there was nothing left at the bank of the river that could be called riparian land, because all the land was owned by the people. These people cleared all the riparian land due to farming and high population density. So with time, all the valleys along the river are all clear, which has resulted to degradation of the land and erosion. So now as the RUA we are trying to restore the glory of the river by planting trees along the riparian area, and also pegging riparian area so that we can dictate what should be planted along the riparian land.

I: How long has Tungu RUA been there?

R: The RUA is over ten years registered in 2009, we have been planting vegetation along the riparian areas. We have also been conserving highly degraded areas along the valleys even if they are not within the riparian areas, conserving even the catchment areas.

I: How have you been conserving it?

R: What we did first was pegging the riparian land from the owners land. Because of the size of the river which is not a very big river, we demarcated 6 meters either side of the river and the tributaries we go up to 3 meters.

I: Are the owners of the land supportive of what you are doing?

R: Actually when we started there was some resistance but we explained to them what we are doing that we are not taking away the land. Luckily, the trees that we have planted in the area have become the source of animal feed and harvesting of firewood, the trees belong to them not to RUA.

I: Any other conservation apart from planting of trees?

R: There is nothing much we have done, maybe on rainwater roof harvesting because there are conflict because of over abstraction of water from the river, abstraction is still there. The only problem we have, is land ownership especially when you talk of swamps, which should have been demarcated as public land, but almost all of them were demarcated as private, and these swamps have been dried up by the owners so that they can use the land. So in the process we are having a challenge, all these swamps have dried up. We still have very few remaining though in very small sizes because of the farming activities going on around them. Those that are public, we are trying to conserve them though we have not succeeded. We are looking for funds to conserve them.

I: Is there any economic value that you normally give to the community to motivate them?

R: Actually we don't have anything to give them, apart from the benefit they get from the trees we have planted because the trees do not belong to RUA but for them.

I: Apart from farming, what else do you think could have contributed to the drying up of the river and its tributaries and the wetlands?

R: The other challenge is quarrying, they blast stones along the valleys. We have very big quarries along Tungu River. This is a challenge because they are drying up the tributaries that they drain their water in Tungu River. Is a major challenge. The other challenge is planting of eucalyptus trees, they have been planted in all even in the wetland and river basin. We are trying to fight it but we still have a long way to go because they are all over.

I: How many small rivers that drain their water in Tungu river sub-catchment?

R: They are over ten tributaries. The length of the river is 25kms, and it has different ecological zones, Forest zone, tea zone/coffee zone, tobacco zone and grazing zone. The conservation in every zone varies, in some parts we are forced to dig troughs so that animals can get a place to drink water instead of direct from the river.

I: Any support you are getting from the county government?

R: No. the county government has not supported as in any way, maybe from different donors like water services trust fund and global environmental facility. Even the

minister for environment in this county has not supported us in any way, we have been consulting them but they do not come in in any way.

I: What about the emergence of high population in the sub-catchment?

R: Yes they are affecting the watershed in great way especially the coming up of Chuka University, a few positive and the greatest are negative. Emergence of Chuka University has forced development of many hostels in the area, you know when we start having many concrete slaps, erosion is a must and the rate of infiltration also reduces, and even funny behaviour within the river because they do not have swimming pools so they have made the river their swimming pools.

I: So this land cover change has been influencing this watershed in a negative way?

R: Yes in a negative way, and that is what we are fighting especially cutting down of trees and also planting of eucalyptus trees along the river because of economic factors.

I: Do we have irrigation in the sub-catchment?

R: Yes we have but not large scale irrigation, it is also a problem because they are also using the pesticides hence polluting the river.

I: You talked of abstraction and drying of wetlands to create room for farming, is there any measures put in place to curb this menace?

R: Formerly there was no serious measures and that is why there has been all these challenges, so there is nothing much that was being done. But now we are trying to sensitize the abstractors, we don't have funds to do that work because it is very expensive. Even the abstractor's records are not available, there are no measures to curb the challenge of drying the wetlands and abstraction, it's now we are trying to come up with some. People are drying wetlands so that they can farm because of the growth in population so they are creating land for farming. We have not gone very far in doing the sensitization work.

I: Does the river have gauge stations?

R: Yes we have 3 gauge stations, one in the forest, another one along the tarmac and the other on the lower side, but some are not working, manned by RUA official.

I: Any information you would like to share about the sub-catchment?

R: The information about Tungu River was not well kept there for us RUA to do our work it's a challenge. Climate change has also been a challenge for us for the last four years, the banks were open with no vegetation hence the rate of evaporation was so high. Before the abstraction became a problem, you could not cross the river but now the width has much reduced and during the dry spell even a child can cross the river. The width is about 5meters. The new crops which the community members are

growing along the river are shallow rooted so when erosion takes place is so massive. On the tributaries, some have dried up they are now like the gorges because they are digging deep to get water. There is also the issue of factories along the river who drain their waste in the river and also using Tungu water in the factories.

I: **Anything else you think has contributed to landuse land cover change within the sub-catchment?**

R: Actually is the population growth. Before we were not cultivating along the river but today people are cultivating up to the last point. Along Tungu river the place so much populated compared to the past years.

APPENDIX VIII: SAMPLE SIZE SELECTION TABLE

Required Sample Size[†]

Population Size	Confidence = 95%				Confidence = 99%			
	Margin of Error				Margin of Error			
	5.0%	3.5%	2.5%	1.0%	5.0%	3.5%	2.5%	1.0%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763
1,000	278	440	606	906	399	575	727	943
1,200	291	474	674	1067	427	636	827	1119
1,500	306	515	759	1297	460	712	959	1376
2,000	322	563	869	1655	498	808	1141	1785
2,500	333	597	952	1984	524	879	1288	2173
3,500	346	641	1068	2565	558	977	1510	2890
5,000	357	678	1176	3288	586	1066	1734	3842
7,500	365	710	1275	4211	610	1147	1960	5165
10,000	370	727	1332	4899	622	1193	2098	6239
25,000	378	760	1448	6939	646	1285	2399	9972
50,000	381	772	1491	8056	655	1318	2520	12455
75,000	382	776	1506	8514	658	1330	2563	13583
100,000	383	778	1513	8762	659	1336	2585	14227
250,000	384	782	1527	9248	662	1347	2626	15555
500,000	384	783	1532	9423	663	1350	2640	16055
1,000,000	384	783	1534	9512	663	1352	2647	16317
2,500,000	384	784	1536	9567	663	1353	2651	16478
10,000,000	384	784	1536	9594	663	1354	2653	16560
100,000,000	384	784	1537	9603	663	1354	2654	16584
300,000,000	384	784	1537	9603	663	1354	2654	16586

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