

Effects of Land Use Changes on Thanantu River, Tharaka North Sub County, Tharaka-Nithi County.

Mercy Mukami Kirema

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Abstract: *Land use practices need to be regulated and managed else they cause harm and cost to the rivers. Rivers play a vital role in supporting these land uses; therefore, there's a connection between the two. Rivers are also vital to human life and when the regime deplete, the life of human and other living things is at risk. Unmanaged land uses cause water stress and scarcity due to the decrease in infiltration and increasing in runoff which cause low flow during dry seasons.*

The study examined effects of land use changes on Thanantu River and was based in Tharaka North Sub County, Tharaka Nithi County. Thanantu River is a permanent river in Tharaka North Sub County and the community highly depend on it for water services. Land uses have caused change in Thanantu River's regime in Tharaka North Sub County. This has led to water shortage within the Sub County as a result of water abstraction for irrigation. The study under-saw the effects of land use changes on Thanantu River in Tharaka North Sub County. It intended to achieve a number of objectives; establishment of land use trends in the last 15 years in Tharaka North Sub County, establishment of effects of land use changes on Thanantu River, determine strategies and effort in place for Thanantu River restoration and alternatives in place due to its fluctuation and come up with mechanisms of restoring Thanantu River. Data was collected through questionnaire administration, interviews and secondary data on the River and land uses.

The findings indicate a spatial change in land uses with forest being the highest in the last 15 years and currently agriculture being the highest. They also show that there has been a change in Thanantu River over the last years. Whereby, these changes have resulted from increased unsustainable, unmanaged and uncontrolled farming practices. These effects include; Loss of flora and fauna (vegetation and aquatic species), Water pollution affecting the quality of the water, reduction in water quantity to extent of drying up and Shrinking of its channel.

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I. Introduction

Rivers ensure there's water in all areas of the earth and drain nearly 75% of the earth's land surface. They play important roles including, habitat for animals and plants, transportation whereby they provide travel routes for recreation and exploration, irrigation, the source of energy where they are used to power machines, sources of food and water for drinking. Therefore they sustain lives on earth.

Freshwater is important for human survival, social economic development, healthy ecosystem and sustainable development. Without water, there's no life. The United Nations Water Conference 1977, the International Drinking Water Supply and Sanitation Decade 1981-1990, the International Conference on Water and the Environment 1992 and the Earth Summit 1992 focused on this vital source which also led to the establishment of World Water Day on 22 March 2005. They helped some 1.3 billion people in developing countries gain access to safe drinking water. (UN Water, 2017). It is an irreplaceable resource and therefore the need for its sustainable management. According to UN-Water, today, more than 1.7 billion people live where water depletion has occurred as use has exceeded natural recharge. By 2025, two-thirds of the population will be living in water-stressed countries. This has led to the need for rivers restoration so as to solve this issue and for sustainable development.

Land use changes are processes by which human activities transform the landscape. They affect water sources especially the natural resources such as rivers. They describe the exploitation and utilization of land resources by humans such as agriculture and urbanization (Guzha et al., 2018). Land uses such as agriculture, forestry, industrialization, and recreation have impacts on water sources through interception, evapotranspiration and soil moisture, therefore, affecting the water cycle. Conversions of forest and conserved areas to agriculture and commercial uses are a common scene in Tharaka North Sub County. (Shi Xiaoliang et al., 2014) In recent years, human activities such as deforestation and farmland reclamation have resulted in significant agricultural-

land pattern changes. This, therefore, has led to the study of the effects of land use change on rivers, which is an important topic in the water resource field.

Agriculture and commercial activities affect the hydrological cycle of a river by interfering with infiltration of surface water and therefore reducing the water levels in rivers. The replacement of forest cover with agriculture and other land uses, increase water yield due to a reduction in water losses as a result of compaction of soil (Sajkumar, 2015). The effect of land uses on river flow and land degradation is one of the most alarming environmental problems.

The rapid increase in population increases the peak flow of surface runoff as it decreases infiltration. This leads (population increase) to an expansion of areas for settlement, commercial and agriculture which may result in changes in river course. These kind of environmental issues are as a result of a change in land uses from forest to agriculture, transport, and commercial. The land uses especially those that affect river directly, result to increase in river sediments and silts due to accelerated and accumulated soil erosion from the activities.

Water usage has been increasing more rapidly than the population increase and this will continue due to increases in agriculture, industrialization and water demand for domestic use (UNDP, 2006). Most of the population reside along river basins and their activities interfere with its water quality. The increase in population leads to an increase in demand for food production, therefore, resulting to river abstraction which negatively impacts river regime.

River regime modification can be caused by the changes in land use, in upstream through the construction of pans and diversion of water from the river for irrigation (Costa et al, 2003; Jianwei, 2017). Irrigation of land changes the distribution of water and therefore negatively impacting the ecosystems that depend on it. The need for irrigation water raises when there are low precipitations thus, leading to reduced river and underground water.

International programmes including the International Human Dimension Program (IHDP), and the World Climate Research Program (WCRP) have initialized some projects to investigate the relationship between land use and the hydrological cycle (Hoff, 2002; Lambin et al., 2002).

Previous studies show that humans can understand ecosystem changes by studying the modes of land use in the past, present, and future (Turner et al., 2003). Therefore the understanding of the effects and repercussions of these land uses in relation to water sources is important for future sustainability. These repercussions include; changes in water demands from changing land use practices such as irrigation and urbanization; changes in water supply and level from altered hydrological processes of infiltration, groundwater recharge and runoff; and changes in water quality from agricultural runoff and suburban development (DeFries and Eshleman, 2004). Results from these researchers indicate that land use changes have a significant impact on the exchange between surface water and groundwater. Land use practices have impacts on both the availability and quality of water resources. (Baker and Miller, 2013) used the SWAT model in an assessment of land use impact on water resources in an East African watershed. From their research, land use changes result in an increase of surface runoff and decrease in groundwater recharge, therefore having negative implications for the river system.

Land use changes in Tharaka constituency and the eastern region at large, have altered the hydrologic cycle of River Thanantu. Tharaka-north is one of the areas that have been experiencing the drastic changes in land use due to an increase in the need for agricultural land. Due to these changes, most of the parts in Tharaka North end up with no water due to river water abstraction. Therefore the impacts of land use changes to water sources are of significance and of great concern as they have led to food insecurity and poverty in the area. This is so as the permanent rivers have been drying up over the years due to changing of forest areas to sub urbanism and other changes in land use which have resulted in a reduction in water levels.

Therefore, research on land use changes in different modes of water utilization and the analysis on reasons for these changes will provide the basis for sustainable planning and management of the watershed environment.

1.2 PROBLEM STATEMENT

Different forms of developmental activities are causing environmental and natural resources degradation which is a growing concern both at national and individual levels (Flint, 2004). Therefore, these developments have resulted in an aberrant changeover of freshwater ecosystems.

There has been a rapid increase in population, reduction in precipitation and an increase in need for food production, for the past years in Tharaka North Sub County, and this has had major impact on Thanantu River which has been encroached by both the farmers and developers so as to meet the need of food production through abstraction for irrigation and provision of settlements through sand harvesting. This has resulted in a decline in water quality and services. With this alteration in the river regime, problems of pollution, loss in biodiversity and water level reduction have been experienced.

Thanantu River in Tharaka North Sub County, Tharaka-Nithi County, has been experiencing variation in water levels and at times drying up yet it's a permanent river. These natural fluctuations together with consumption by humans and changes in land use over time have led to depleting of the river. The river supports both economic and socio-development activities such as irrigation, domestic supply, construction activities and fishing. Moreover, these benefits could be threatened by land use changes and climate change.

Unless measures and strategies are put in place to improve water resource management and use, the water condition will go on to worsen due to changing in water use pattern. Within the last 50 years, the ecosystem has been altered (MEA 2005) as most of the population live in river basins thus depending so much on the river water for food production and other domestic uses. Land use practices impose damage to water sources and more so rivers. Water problems in Tharaka North Sub County are experienced as most of the residents are farmers and tend to maximize output from land use activities without considering the effects they may have on other resources. Weirs for upstream water abstraction are one of the major activities practiced by the people of Tharaka North Sub County which has efficacy on Thanantu River regime, which causes water scarcity.

Land use changes such as commercial and agriculture within the river ecosystem and basin is of concern. Results from previous studies on water resources show that nutrient loadings into the rivers originate from the upper parts of the water sources. It's hypothesized that the population pressure on the upstream side of the river, has resulted to an increased flow of sediments and nutrients into the river and therefore the water source undergoing changes, such as turbidity and reduced water level.

River Thanantu passes through and near agricultural lands owned by individuals who claim the ownership and protection of the river. They impose challenges to the river through abstraction and make it hard for others to fetch and acquire water from the river. The land use practices undertaken in Tharaka North Sub County have an impact on Thanantu River which is the main source of water for the people. Therefore there's the need for better management and utilization of rivers and land uses to avoid their degradation and depletion.

The area has a number of rivers both permanent and seasonal. The permanent rivers, whereby Thanantu is one, have slowly dried up especially on the downstream side. Population increase, demand for food for both consumption and commercial- having that the core activities in the area are farming and reduced level of precipitation has led to both obstruction and abstraction of water. This has greatly affected the water levels in the river, therefore, causing water shortage as the majority of the population depend on it as a water source. These benefits highly call for the restoration of the river. The purpose of this study was to investigate the effects and mechanisms of Thanantu River restoration in reparation of water shortage and scarcity in the area.

1.3 RESEARCH QUESTIONS

The study will attempt to answer the following questions.

1. What are the land use trends in Tharaka North Sub County?
2. What are the impacts of land use changes on the Thanantu River?
3. What restoration strategies are there in the rehabilitation of river Thanantu and what alternatives have been put in place due to its fluctuation?
4. What measures can be undertaken to ensure protection and conservation of Thanantu ecosystem?

1.4 RESEARCH OBJECTIVES

1.4.1 General Objective

The general objective of the study is to find out the effects of land use changes on Thanantu River in Tharaka North Sub County.

1.4.2 Specific Objectives

The study will attempt to meet the following objectives.

1. To establish land uses up to last 15 years in Tharaka North Sub County.
2. To establish effects of land use changes on Thanantu River.
3. To determine strategies and efforts in place for restoration of Thanantu river and alternatives in place due to its fluctuation.
4. To come up with mechanisms of Thanantu River restoration.

1.5 RESEARCH PREMISES

The study will be guided by the following premises.

1. There have been changes in land uses over the last years in Tharaka North Sub County.
2. Land Use changes are of concern to Tharantu River ecosystem and basin.
3. There is a relationship between river flow and changes in land use in Tharaka North Sub County.
4. The community has contributed to the river ecosystem depletion.
5. There have been restoration mechanisms put in place.

6. Efficacious restoration requires ample planning and continuous monitoring.

1.6 JUSTIFICATION OF THE STUDY

Water is an important resource that needs to be well utilized for everyone to access. Water accessibility is very low in rural areas where most of the people depend on rivers as their source of water. The inefficiency of the water is caused by rainfall variability and land uses. Tharaka North Sub County experiences water stress and scarcity because of the likely land uses activities necessitated by the abstraction of river water.

Thanantu River is a major source of water that serves and facilitates the people of Tharaka North Sub County. Over the past years, its course has changed to an extent of becoming a seasonal river. Cutting down of trees on the upstream and abstraction of its water for irrigation and other domestic purposes have led to its depletion and changes in its state. This has led to water scarcity in the area. The reduction in its discharge has led to the reduction in its benefits. The restoration of the river to its original state will be of great benefit to the people of Tharaka. To solve this issue, there have to be restoration strategies and policies put in place and implemented by the Government, NGOs and Community.

Land use changes especially the conversion of forests to agriculture, development, and settlement, increases surface runoff and stream flow leading to an increase in sediment transportation, therefore, causing a reduction in water quality and levels. River Thanantu has incurred these kinds of changes over the last few years with water level reducing and to some extent drying up. This has been so due to changes of forest to agriculture where water from the river has been abstracted for irrigation purposes.

Information on the restoration of the river and the reasons for drying up of permanent rivers like Thanantu will provide the foundation and better management of rivers, thus solving the issue of water scarcity. This, therefore, necessitates the importance of studying the extent of land use change and its impact on the Thanantu River. Data from the study will be used by both the community and relevant authorities in the management of the river, designing of rainwater detention structures and construction of other water sources such as boreholes and dams, therefore, saving the rivers in the region from abstraction.

The study has provided information that can be used in the formulation of policies on land uses and understanding of the relationship between land uses and water resources. It has also provided measures to address the current issue facing Thanantu River. These measures deal with the efficient use of water from the river for agricultural and domestic uses. It will also serve as an awareness tool as ensures land use change implications, which are as a cause of human activities, are well understood for proper management of water resources and sustainably. Therefore this will eradicate the issue of water shortage and scarcity. It aimed to understand the land uses in the area, their changes and effects on River Thanantu, impacts of human activities on the river's water level, and the establishment of alternative water catchment method from the river for irrigation and river restoration mechanisms.

1.7 SIGNIFICANCE OF THE STUDY

The study provides information on land uses practiced in Tharaka North Sub County and their effects on Thanantu River. It involved the relevant authorities and stakeholders in Tharaka North such as the Ministry of Lands, Irrigation Projects Authorities, and the local communities. It examines both present and previous land use trends in the area and their impact on Thanantu River and in addition, the study came up with measures to improve conservation of the river, its restoration from depleting state and established the need for watershed conservation awareness to the community and need for better farming practices.

The findings of the study could be used by not only the constituency government of Tharaka and Tharaka-Nithi County at large but also in the restoration of rivers nationally in order for the achievement of SDGs in the eradication of poverty and clean water, in relation to vision 2030, as water plays a vital role in life and universe.

1.8 SCOPE OF THE STUDY

The study was based in Tharaka North Sub County in Tharaka constituency, a semi-arid area, which is one of the three constituencies in Tharaka-Nithi County. It covered River Thanant's environs. The study area is 179 kilometers from Nairobi with a driving hour of approximately 4 1/2 hours. It borders Meru County to the North, Kitui to the East and South East and Embu to the South. Tharaka Constituency is bordered by Maara and Chuka constituencies of Tharaka-Nithi County.

The study focuses on the effects of changes in land use on river Thanantu. The variables measured and determined were land use patterns in the area, impacts of the land use to Thanantu River, community involvement in river changes and climatic conditions and seasons.

1.9 LIMITATIONS OF THE STUDY

During the study, the problems faced included;

Limited time

To be able to acquire information from authorities, one needs to book an appointment. This, therefore, requires time so as to be able to meet with the person. This limits the data collected as the area the River covers a large area but only part of it can be covered.

Uncooperative response

During the study, the researcher came across uncooperative responses from the local people and some filling the questionnaire halfway. Some of the locals were resistant to information sharing and therefore not free to take part in the research. This limited transparency of the data and its accuracy.

A Large area of coverage

The area of the study area was wide and therefore the researcher was unable to cover the whole of it as the River flows along a wide area. Therefore this results in coverage of only a selected area.

Inadequate institutional representatives

The study area lacked active relevant authorities such as WRA and WRUA. There was also a limitation of data in the relevant institutions as the officers were new and didn't have adequate knowledge and information of the variables. The information was dependent on the immediate county which was not the area of study. This, therefore, limited accuracy of data and acquisition of all the relevant information.

These limitations, therefore, hinder successfulness of the research hence reducing the level of accuracy.

1.10 OPERATIONAL TERMS

1) River discharge:

Refers to the volume of water that passes a given cross section in the channel during a specified time interval, measured in m³/s.

2) Land use:

Involves management and modification of natural environment into the built environment.

It's the total arrangement, activities and inputs that people undertake in a certain land cover type.

3) Land use change:

The process by which human activities transform the landscape.

4) River regime:

The pattern of the seasonal flow of water in a river.

5) River Abstraction:

A process of taking water from the river.

6) River restoration/ reclamation:

Set of activities that help improve the environmental health of a river.

Activities that restore the natural state and functioning of the river system.

7) River Depletion:

A long-term water-level decline in the river.

II. Literature Review

2.1 INTRODUCTION

Land use is the function of land and what it's used for (O'Sullivan, 2015). There is different types of land uses, namely; Commercial, residential, industrial, institutional, recreational, agricultural and transport. Land uses vary in different regions whereby different areas have different land uses. In rural areas, the land uses are mostly forestry and agriculture while in urban regions they are mostly commercial and industrial. Land use is an important factor that influences river flow and regime (Ann, 2007; Guzha, 2018).

The land use models have zones which include; central business district, Inner-city, suburbs and Rural-Urban Fringe. The CBD is characterized by shops, financial institutions, offices and businesses as it's the commercial center in urban areas. It has limited open spaces, the land value tend to be high, the buildings are tall, main transport system lead to the centre, development is mostly done to the existing ones rather than developing the open spaces, has limited number of houses and flats due to high land values and above all, the population is dense. The inner city zone is characterized by linear housing patterns, gridiron streets, land value is lower than that of CBD and population is dense. Suburb Zones mostly contain semidetached private houses, the population is medium (neither dense nor sparse) and the land value is low. Rural-Urban Fringe has mixed land use which includes residential, recreational and agriculture. The land value is low and therefore the houses here are of better quality and more spacious. The houses are both privately owned and council-owned whereby the council houses have a higher density than the private and the housing typology is flats and tower blocks.

According to the Intergovernmental Panel on Climate Change 2017, Land use change is the change in the way the land is used. Whereby, forests are cleared for agricultural use or residential. It further explains that conversion of forest, grassland and woodlands to pasture and other managed uses is one major land use change

that causes a rise in carbon IV oxide emissions. Some of the lands uses such as agriculture have a direct effect on water sources (Owino, 2007).

Deforestation and land cultivation affect water cycle as they interfere with infiltration and runoff, thus interfering with evapotranspiration and groundwater recharge. Crop irrigation occurs when there are insufficient rainfall and this result in reduced groundwater levels and a change in the distribution of land (Vandas et al., 2002). Clearing of the forest, vegetation cover, and increase in agriculture has resulted in riverbank backflow especially during rainy season. This is so, due to sediments depositional at the river mouth. Therefore, land use changes occur due to human interference which is occurring at an alarming rate as they cause biodiversity degradation (Slingenberg, 2009).

The major changes in land use are the conversion of forests to agriculture due to increase in demand for food production. The two land uses are related and linked to water and biodiversity. Therefore, they highly have effects on the water cycle. It's estimated that the increasing population will require more food resulting in an increase in water demand for agriculture from the current level of 7,130 km³ to 13,500 km³ in 2050 (United Nations, 2012). This will result in water stress and scarcity which is already being experienced in dry and semi-arid areas. About 25% of river basins run dry before reaching the ocean due to water use (Molden et al., 2007). It's estimated that about 2.3 billion people lived within river catchment areas with water shortage (Revenga et al., 2000). By 2025, 48% of the world population will be living in water stress where it will be as a result of freshwater withdrawal for irrigation (UN Water, 2016). Therefore the increasing water stress calls for strategies, management systems, and policies to address this issue.

Global Land Use Change

There has been a change in the earth's surface over the years with forest being converted to farmlands. Land use changes have an impact on the global biodiversity and contributing to global climate change (Mngoli, 2014). Most of the land uses have changes in different countries of the world. For instance, in the United State 46% of its population lived in urban centers in 1910 while as of 2010, 81% lived in the same urban areas. Over the years the land under agriculture has declined from 52% as in 1949 to 52% as of 2012 (Daniel, 2017).

Sub Saharan Africa Land Use Change

Sub Saharan Africa is sustained by land but has been experiencing land use changes over the years. Land use changes have an impact on biodiversity and cause land degradation (Lambin, Geist and Lepers 2003). In Africa, forest land use occupies 23% as of 2010 and between 1990 and 2010 10% of this land use had been converted to other uses such as agriculture (FAO 2016). For instance, between 1990 and 2000s there was a 1.4% decrease in the forest with a 1.4% increase in agriculture in Malawi (Latham et al, 2014). This, therefore, has led to a decrease in animal and plant habitat, soil erosion, water stress and land degradation (Food Agriculture Organization, 2017).

Pressure on water sources has been experienced due to increase in population which has led to a competition of natural resources in sub-Saharan Africa such as water, due to the need of more land for agriculture and settlement (FAO, 2011). Urbanization and deforestation are the major changes influencer in Africa. Water stress in Africa is mainly attributed to land use changes as these changes have a great impact on water quality, decreasing in groundwater and reduction in the volume of water and therefore leading to water stress.

Land Use Change in Kenya

There are different land uses in Kenya which includes; Agriculture, Commercial, infrastructure, residential, recreation and forest (National Land Use policy, 2016). According to National Atlas, 2004, 2.2% of Kenyan area is water surface while 97.8% is land mass but due to estimated increase in population which by 2030 is approximated to be 71 million from 40 million as of 2014 (Population Census Report, 2009) will reduce the percentage of land occupied by vegetation, therefore, leading to reduction in water mass. Due to demand for more land for agriculture and settlement, there have been tremendous changes in land uses over the years. Population growth has resulted in urbanization and this has exerted pressure on the existing land uses such as agriculture due to demand of land for settlement (Musa&Odera, 2015). This has resulted in problems such as food insecurity and water stress.

For instance, in Taita Hills of Kenya, landsats shows that in 1987 there was more land under vegetation/ forest with less land under agriculture, while in 2003 the land sets show that there's reduction in land under forest, increase in land under agriculture and decrease of water surface.

Land Use change in Tharaka

Historically, the Tharaka people relied on livestock keeping in large grasslands. Due to external and internal forces, there was an increase in demand for production of crops which lead to some of the land used for

grazing being converted to farmlands. For instance, in the 1970s, there was population growth and land degradation which lead to land shortages (Smucker, 2002). By 2015 there was a very low percentage of land for grazing as most of the land had been converted to settlement and agriculture purposes which lead to those still keeping livestock to look for pastures elsewhere. These changes have brought about effects such as water shortage, land degradation as they exert pressure on the natural resources.

2.2 TYPES OF LAND USES

There are different land use practices across the world. The United Nations Food and Agriculture Organization water Development Division 2004, states that land use concerns the importance produced from the use of the land, its resources and management activities practiced by the human to produce the benefits. There are different types of land uses, namely: Commercial, Residential, Agricultural, and Recreation (Biswajeet, 2017). In the 19th century, most of the land was considered arable land where 26% was pasture, 32% forest and woodland and 1.5% urban areas.

Residential land use

It's whereby the land is used for residential purposes and can support housing and residential environment. The housing may take many forms ranging in density and scale from detached homes to high-rise apartment structures. They are of different types; Flats, maisonette or Bungalow.

Transportation land use

Any land used for transportation systems like Roads, Parking lots, Railway networks or Airport networks and terminus.

Commercial land use

This is whereby land is used to conduct commerce. It contains services that bring income such as businesses.

Institutional land use

This is a land which is set aside for learning institutions and administrative institutions.

Recreational land use

Describes a land use type where land is set aside for recreational purposes such as a stadium, parks, nature trails and open spaces.

Industrial land use

Land that is set for the establishment of factories and industries, both the manufacturing and processing, heavy industries where larger pieces of lands are required and pollution is high as well and light industries which are smaller.

Agricultural land use

There are different types of agriculture types which include simple subsistence farming /shift cultivation, intensive subsistence agriculture, and plantation agriculture. Simple subsistence agriculture is whereby the farmers grow food only for consumption by themselves (Sanjudohray, 2010) whereas intensive agriculture high output per unit of land and low output per worker. Plantation agriculture is practiced in ranches of land where cash crops are grown.

The land is used for the purpose of food production and other agricultural practices such as fiber commodities, livestock and poultry, bees, fruits and vegetables, sod, ornamental, nursery, and horticultural crops that are raised, grown, or produced for commercial purposes and also for subsistence.

In countries like South Africa, the county's land uses are Agriculture 79.4%, Arable Land 9.9%, permanent crops 0.3 %, permanent pasture 69.2%, Forest 7.6% and others 13% (2011 est.). In Kenya, the land is used differently depending on the culture, social, and political factors. Moreover, the people setting in the area determine the land use measures (Kenya Land Alliance, 1999). They include; Agricultural, Residential, Commercial, Industrial, Recreation (Nema,2011) where according to 2011 est. agricultural land occupies 48%, Arable land 9.8%, permanent pasture 37.4%, forest 6.1% , Others 45.8% (CIA World Factbook 2017).

In the Eastern Region of Kenya, Urban area occupies 32.34% while Rural is 67.66% (KNBS 2009). The rural area is mostly occupied by agricultural land use.

In Tharaka North Sub County, the land uses include; Agricultural, Residential, Institution, Industrial, Recreation, Transport, Commercial, and Forest. The Agriculture includes farmlands and irrigation; Residential include houses; Institutions include; administrative units and Schools, Industrial include Sand Harvesting, Recreational includes National Park and Tourism sites, Transport includes Roads, Commercial includes businesses. The dominant is the agriculture which is an economic aspect due to food production for both commercial and subsistence purpose.

2.3 LAND USE CHANGES

2.3.1 Causes of land use changes

They occur either due to land modification or conversion. They are caused by the natural environment and demographic, economic, social, political and institutional factors. These factors include; climatic variation, population pressure, topography, soil type, volcanic eruptions and economic factors (Lambin, 2003).

These factors result in demand for more land for settlement, development, and agriculture. This pressure leads to conversion of forested and recreational areas to land for agriculture due to increase in food production demand and land for settlement and other developments.

2.3.2 Impacts of land use changes

Land use changes have various and major effects on water sources and the environment in general (Erle and Robert, 2013).

Climate change

Land use change releases greenhouse gases into the atmosphere, therefore, leading to global warming. This is so as it increases carbon IV oxide balance to the atmosphere through disturbance of vegetation and terrestrial soils. More than 50% of the world's freshwater originates from mountain runoff and snowmelt. Climate change threatens these freshwater sources and leads to water shortages due to the warming up of temperatures, as it increases water demand while decreasing water supplies. As temperatures rise, there's a need for more water. Therefore this impact of climate change such as water quality affects other sectors such as energy, agriculture, and ecosystem (P. Fleming, 2014).

Pollution

The environment pollution is contributed in by land uses changes such as clearing of trees and vegetation cover. Deforestation makes the soil vulnerable and easy to be eroded by both wind and water. This causes degradation of soil fertility which has a negative impact on farming. Pesticides and herbicides used in farming, cause water pollution through the release of toxic chemicals into the body. Pollution on water sources makes the water quality unsuitable for consumption and reduction of the water volume. It also leads to the death of organisms that depend on water sources.

Loss of biodiversity

Land use changes have resulted in the loss of biodiversity which over the years has been diminishing. This is through the conversion of forested land to farming where tree species are lost. Reduction in tree species or forested areas means a reduction in water levels in water sources as some like rivers, originates from the forests. In areas that there's no vegetation cover, there's water stress and drying up of water sources. There's a relation between forest and water in that they act as water catchment areas, protect water quality, capture silt and sediment, filter water and prevent erosion (World Resource Institute, 2017). (Filoso, 2017).

Water stress

Land use changes such as conversion of forest to agriculture land, result in water stress. This is due to that the water from water sources like rivers is used for irrigation. This may lead to overusing of the water due to abstraction, therefore, causing drying up of the water source, thus influencing the availability of water. Land uses to interfere with the hydrological cycle as they cause more evaporation and runoff.

2.4 LAND USE CHANGE TREND

Converting of land use from farmlands to residential or commercials causes a change in spatial distribution of the population. The landowners influence what happens on the land through the decision they make on land use as they quantify the changes (Ettema et al 2007). Different type of landowners decides what to do with their lands and the parameters to use. Their awareness of the economic situation can control the speed of changes, as the landowners whether farmer, developer, private individuals or government, supply the financial investment of the land change. This is so as the owner can make several decisions which can bring about land changes. They include:

- Develop the land by changing how it's used and exploit it.
- Leave the land or use it is in the current situation.
- Sell the land to another person who might decide to utilize it for another purpose.
- Develop the land by changing the land usage and selling it.

Options and decisions may vary for some owners as one may want to come up with a development but has constraints like required skills and capital. Different types of owners have different ways of utilizing their land. Where the Farmer will exploit it, sell or buy, Government will sell to farmers, maintain, sell to a developer

or develop while the developers will develop and sell, redevelop and exploit. Therefore the decision that will be made is highly linked to the owner as will do and make that which is of value to him/her (Ettema et al 2007). Thus land use changes trend depend highly on the decision of the owner and the trend change periodically.

2.5 EFFECTS OF LAND USE CHANGES ON RIVERS

River flow alteration.

Cultivation near the river shores, intensify erosion and increase the sediment load in rivers. This reduces flood capacity and instream flows. Demand in water for irrigation lead to abstraction which results to reduced river regime due to interference with water distribution. Deforestation interferes with infiltration and runoff (Vandas S et al 2002). River flow is altered through water magnitude, reduction in surface and subsurface water levels. This reduction in the flow of the water reduces the volume of water thus affecting the adequacy of it being used and relied upon by the human population. Most of the arid and semi-arid areas the flow of the rivers is no more due to the increase in water abstraction thus changing the nature of the river.

Drying up of the river.

Conversion of forest areas to agricultural land has led to the drying up of the rivers. This is due to that forest act as water catchment areas.

Water pollution.

Land use changes cause pollution on rivers as industries and commercial centers mainly will discharge their waste in the river. According to UN an estimated 2 million tons of industrial and agricultural waste is discharged to the world's water supply whereby river is one of the major water supply of the world (United Nations World Water Assessment Programme, 2003). Nutrients, pesticide, chemicals, and fertilizers from farms may drain or seep into the river system, therefore, affecting water quality, leading to the death of species due to de-oxygenation and increasing the plant growth.

Overexploitation of aquatic species. E.g. fish.

The land use changes especially where there is an introduction of commercial centers, lead to overexploitation of fishes from the rivers which affect the long-term sustainability of species population.

2.6 RIVER DISCHARGE FLUCTUATION

River discharge is the volume of water flowing along a river channel at a given time. Water levels are dependent on various factors such as precipitation, evaporation, temperatures, climatic conditions and outflow of human activities.

Fluctuations of river regime are directly linked to flooding and drought. These characteristics make it a subject of interest as through understanding of these seasonal fluctuations can improve the prediction of river flow changes and level of flooding and drought (Hirpa, 2010).

2.6.1 Factors Affecting River Discharge

River discharge is affected by various conditions both natural and human factors (Jonathan, 2012).

- Weather Conditions

During high temperate periods, there's increase in evaporation from the river and this reduces river discharge while prolonged cold weather conditions may lead to frozen grounds therefore when it rains instead of the precipitation soaking in, it runs off to the river, therefore, increasing the river discharge. Hot dry weather bakes the soil, therefore, hindering water infiltration during rainy days. This result to increase in river discharge as the runoff flows straight into the river channel.

- Rainfall

Heavy rains result in increased river discharge as more water flows into the river. Saturated ground due to antecedent rainfall leads to water flowing into the river in case of continued rainfall.

- Soil type

The type of soil affects the river discharge in that sandy soil absorbs water and therefore rare surface runoff which reduces discharge while in areas with clay soil, the water gets to the river faster as the soil doesn't allow infiltration of the rainwater.

- Land use

Poor farming practices in rural areas such as ploughing along instead of across create channels which allow rainwater to flow into the river and in urban areas, land use such as transportation especially where the roads are tarmacked, it's impermeable therefore the water collects in drainages which later spills over into the river.

Deforested areas don't hold rainwater; therefore, the water flows into the river which increases the water into the river.

- The building of dams and canals

Dams and canals result to decrease in river discharge as there's more water outflow than inflow.

- Placing of logs and throwing of garbage onto the river.

2.7 RIVER RESTORATION

2.7.1 River Restoration Mechanisms

River restoration is the act of recovering ecological structure and function of degraded river ecosystem and re-establishment of necessary processes that support the natural ecosystem and to improve the ecosystem services a river provide (UNESCO, 2016).

River restoration is necessary so that it can provide the services it's supposed to and to eradicate water scarcity. It helps in balancing the needs for freshwater ecosystem services of the people and the pressure on river ecosystem. Therefore it raises the need to understand the relationship between river functions and human impacts on the river. It involves addressing both passive and active restoration measures such as water quality, changing the landscape and policy measures (UNESCO, 2016).

River restoration involves active restoration such as direct interventions in the modification of the river system or passive restoration which involves changing systems of the human such as regulatory measures, awareness, and policies (Roni and Beechie, 2013).

River restoration is considered in three dimensions;

a. Spatial Scale

This is whereby different restoration measures are undertaken within the river basin. The understanding of spatial scale is important so as to understand both ecological and political dimensions and also understanding scale at which river basin processes occur for effective response formulation. It helps in restoration strategy and policies, especially where the river crosses administrative boundaries.

b. Timescale

This is to be applied in terms of time when measures and improvements should be implemented. The time scale dimension helps in achievement of restoration objectives successfully and within the time frame.

c. Range of measures

It's in terms of the activities to be undertaken so as to achieve restoration objectives.

2.7.2 River restoration measures

a) Catchment management

Catchment management includes all measures that look into water quality and river regime. Some of the measures include regulatory controls over land use (UNESCO, 2016). Water quality is highly dependent on water flowing into the river which can be affected by both land cover and the position of the river network (Le Maitre et al., 2007). This, therefore, means that most of the river depletion has linkage to land use practices. By addressing factors that have affected catchment such as materials that flow into the river and the water quantity, restoration of a depleted and degraded river can be achieved (Gilvear et al., 2012). These mechanisms include; policies that control land use changes such as deforestation for agricultural and developmental land, land and water conservation, reduction of runoff in rivers through flood risk management measures (Glendell and Brazier, 2014) reduction of agricultural pollution diffusion into the river through establishment of buffer zones between farms and the river, fencing eroded river banks (Catchment Restoration Fund, 2014). These restoration mechanisms can be affected by awareness and regulations by individuals.

b) Flow modification

These are the measures that look upon river regime by regulating flow in terms of volume, frequency, and duration. Some of the measures include stormwater management and retrofitting of dams. Flow changes due to abstraction affect the roles of a regime such as maintaining natural patterns of upstream-downstream and river-floodplain and determining physical habitat in rivers. Therefore these roles bring about the need to consider the river regime in restoration.

c) Dam and barrier retrofitting

This entails measures that address negative impacts to the river as a result of dam construction and barriers. These facilities have impacts on the rivers such as degradation of river channel through trapping of sediments, blocking migration of aquatic organisms, seasonal fluctuations due to flow regime changes and habitat fragmentation (World Commission on Dams, 2000).

d) Rainwater management

It Involves measures that control the release of rainwater runoff into the river and those that improve quality of water flowing into the rivers especially from urban areas. This involves the construction of structures that will

regulate the flow (UNESCO, 2016). Rainwater management measures aimed at restoring flow regime, habitat and biota through minimization of urban impacts.

e) Riparian management

It includes measures that aim at re-vegetation of the zone around the river. The Riparian zone acts as a buffer between the river and the surrounding practices. It traps sediments that are running towards the river source and helps infiltration, shade which controls the temperatures of the water. Therefore it aims at controlling erosion; improve water quality, control weed, biodiversity enhancement, and recreation.

These management measures include controlling of land use so as to limit the removal of riparian vegetation, exclusion of livestock directly to the river through the establishment of water points, revegetation of the zone and removal of weeds.

f) Re-meandering

This is bringing back the curves of a natural river. It creates space, increases drainage and flood protection. It also enhances passage of fish.

2.7.3 Importance of River Restoration and Rehabilitation

Rivers provide natural, economic and societal services. River restoration is important as it's a measure of mitigating the effects of climate change and habitats for animals (Ellen, 2015). They connect habitats both between downstream and upstream areas and river banks. Therefore this brings about the importance of management of the river.

River restoration is important as it restores the ecosystem, adaptation of biodiversity, increase water storage, improve water quality, reduce flood risks, provide shade and reduce temperature and promote fish migratory movement.

Restoration of rivers in the urban area especially in the parks provides free, accessible and safe recreation for people.

Rivers act the role of connecting communities and bonding, especially where it passes through two states. Therefore its restoration enables communities to mix which promote social cohesion.

River restoration improves environmental aesthetic through the restoration of flora and fauna and improvement of the surrounding through re-vegetation and tree planting (Latha&Parineeta, 2012).

Preservation of cultural belonging as in some communities they attribute spiritual rites and value to rivers.

2.8 CASE STUDIES OF PERMANENT RIVERS DRYING UP

Researchers from the US-based National Center for Atmospheric Research analyzed data of 925 river flows from 1948 to 2004 (Katherine, 2009). After the analysis, a third of the rivers had changed inflows including the Ganges in South Asia, Niger in West Africa and the Yellow River in China which were found to dry. This was as a result in reduced run-off due to increase of demand for water by the population. The loss of river water is as a result of usage for agriculture and installation of dams.

Lake Chad had contracted by 95% between 1963 and 2001 with the evidence of satellite images (Mark &Obijiofor, 2009). According to UNEP, about half of the drying up has been due demand for agricultural water.

Rivers in most of Mt, Kenya region have dried up with some having no water flowing. This is due to the draining of the water from the rivers by upstream users where downstream users source water from other sources.

2.9 POLICY, LEGAL AND INSTITUTIONAL FRAMEWORK

These policies, institutional and legislative frameworks relate to the conservation, management and protection of water resources.

2.9.1 Policies and legislations Framework

Table 1: Policies and legislation framework

Policies	Responsibilities and Roles in regard to Water sources
Constitution of Kenya 2010	Article 43 of 2010 Kenyan constitution states that everyone has right to clean and safe water in adequate quantities. It further indicates the function of the national government in relation to water as water protection, securing sufficient residual water, hydraulic engineering, and safety of dams in section 22. Section 11 states water and sanitation as a responsibility of the county government. This, therefore, means the national government has a role to oversee the development of water resources while the county government oversees the operations of both water and sanitation services.
Vision 2030	Aims to transform Kenya into a newly industrialized country by 2030 and recognizes water as a major contributor to this goal. It also recognizes water management as industrial development. The National Water Master Plan 2030 focuses on the following in the water sector; i. Improved water and sanitation are available and accessible to all by 2030. ii. Increase agricultural area under irrigation to 1.2 million hectares.

	<p>iii. Be a nation with the Clean, secure and sustainable environment by 2030.</p> <p>iv. Generate more energy and increase efficiency in the energy sector</p>
Environmental Management Coordination (EMCA) Act 1999 Amendment 2015	<p>The act establishes appropriate legal and institutional framework for the management of the environment of Kenya and also it provides a framework for integrating environmental considerations into the county's overall economic and social development.</p> <p>It provides a comprehensive legal institutional framework for the handling of all environmental issues in Kenya.</p>
Water Act 2016	<p>The Act generally provides for the regulation, management and development of water resources, water sewerage services and for other connected purposes.</p> <p>The act gives responsibility for contracting and appointing water service providers to agencies like Water Resources Authority (WRA), Water Services Regulatory Board (WSRB), Water Appeal Board (WAB) and Water Services Trust Fund (WSTF). The agencies are also responsible for better water supply, financing and sewerage services provision.</p> <p>The act gives priority to use of abstraction water for domestic purposes over irrigation and other uses.</p> <p>Provides for the establishment of WRUAs, which are community-based associations for collective management of water resources and resolution of conflicts concerning the use of water resources.</p>
National Environmental Policy 2013	<p>It proposes measures and actions responding to environmental challenges and issues. It provides a framework for an integrated approach to planning and sustainable management of natural resources. Further, it recognizes different vulnerable ecosystems and proposes various policy measures and recommends strong institutional and governance measures to support the achievement of the desired objectives. The policy helps in the conservation and management of resources such as water</p>
National Land use guidelines	<p>It gives guidelines on the protection of groundwater, rivers, lakes, and wetlands.</p> <p>The guidelines for rivers in Kenya are intended to:</p> <p>Provide buffer zones between 2m-30m which measured from the highest watermark for rivers depending on the width, water volume, whether permanent or seasonal and the uses of water.</p> <p>Establish Water Resources User Associations (WRUAs) and develop allocation plans to minimize water use conflicts.</p>

2.9.2 Institutional framework

These are organizations which are in charge of formal laws, regulations and service provisions.

Table 2: Institutional framework

Institutions	Responsibilities and Roles
National Environment Management Authority	<p>The authority's function in regard to water resources are promoting conservation and utilization of freshwater resources, implementation and development of wetlands Policy, ensure proper management and utilization of environmental resources sustainably and to examine land use patterns so as to determine their impact on the quality and quantity of natural resources.</p> <p>Therefore it's the government's monitor in ensuring the management and conservation of water resources</p>
Water Resources Authority	<p>WRA is a lead agency and corporation under the ministry of water and irrigation under Water Act of 2002. The act governs the responsibilities of the agency in that it provides for decentralized and stakeholder involvement. This is implemented through regional offices of the authority based on catchment areas, assisted by Catchment Area Advisory Committees. Stakeholder involvement will be through Water Resource User Associations. Among its functions are management and protection of water catchment areas and resolving conflict arising from water use.</p> <p>It's responsible for regulation and protection of water resources quality from adverse impacts.</p> <p>Management and protection of water catchment.</p> <p>Gathering and maintenance of information on water resources and periodically publish forecast, projections, and information on water resources.</p> <p>Advice the minister concerning any matter in connection with water resources.</p>
Water Resource User's Association	<p>It's responsible for the management of water resources in a river sub-catchment.</p>

2.10 THEORETICAL FRAMEWORK

2.10.1 Rural Land Use Models

Land use models explain the layout of different areas. They are used for one to understand real-world situations. There is one model which is applied: **the Rural Land Model.**

Cultural History Theory by Carl Sauer (1889-1975) - The theory based its information on impacts of humans on the environment. It was on the bases that Carl had a belief that agriculture had an impact on the physical landscape where he concentrated on the cultural landscape which included general geography, regional geography, and environment relations.

Ester Boserup (1910-1999) – Model by an Agricultural Economist which bases its information and theory on the human-environment relationship. It states that the challenge starving population caused by exponential growth overcoming agriculture geometric (Malthusian Theory), can be addressed by advanced agricultural practices and technology.

Von Thunen (1783-1850) –Model that was based on the cost of land and transportation cost. The near the land is to an urban area, the more it will cost, therefore the farmers have to balance transportation cost, land, profit and produce the most effective product to the market. The theory explains that there might be an agricultural pattern around a city which would include ranching, intensive farming, field crops and forest.

2.10.2 Approaches to land use change modeling

Help in understanding the ways in which the human change the systems of the earth in the past, present and future and help in formulating policies that are sustainable. Changes in land use affect the climate and environment. Land use Changes necessitate decisions and policy-making in consideration of the land system thus resulting in positive societal and environmental outcomes (Agarwal, 2002). These models include;

a) Agent-based model

This model simulates the behavior of individuals making independent choices and their effects on the landscape. The model uses theoretical data rather than empirical (Crook, 2006).

b) Cellular Model

It uses maps for various types of land use to compare areas that are adjacent to project changes and variations in the scale of cells in a cellular model which may have an impact on model output. Use discrete spatial units as the basic units of simulation and the information simulate the conversion of land use in land units based on rule set and applied on all spatial units that represent the modeller's understanding of the land change process.

c) Machine learning and statistical model

The model uses approaches which generate maps to show a relationship between inputs and outputs of land use changes. Uses land cover data using datasets from the past to access and determine how land will change in the future.

d) System dynamics model

This model was developed by Jay Forrester in 1950s. The model was used in addressing of supply chain management problems. It operates a wide range of levels and scales to address specific modeling objectives. The Data usage range from qualitative empirical used in deriving a decision rule to quantitative empirical data to provide input parameters that shape the strength of feedback relationship.

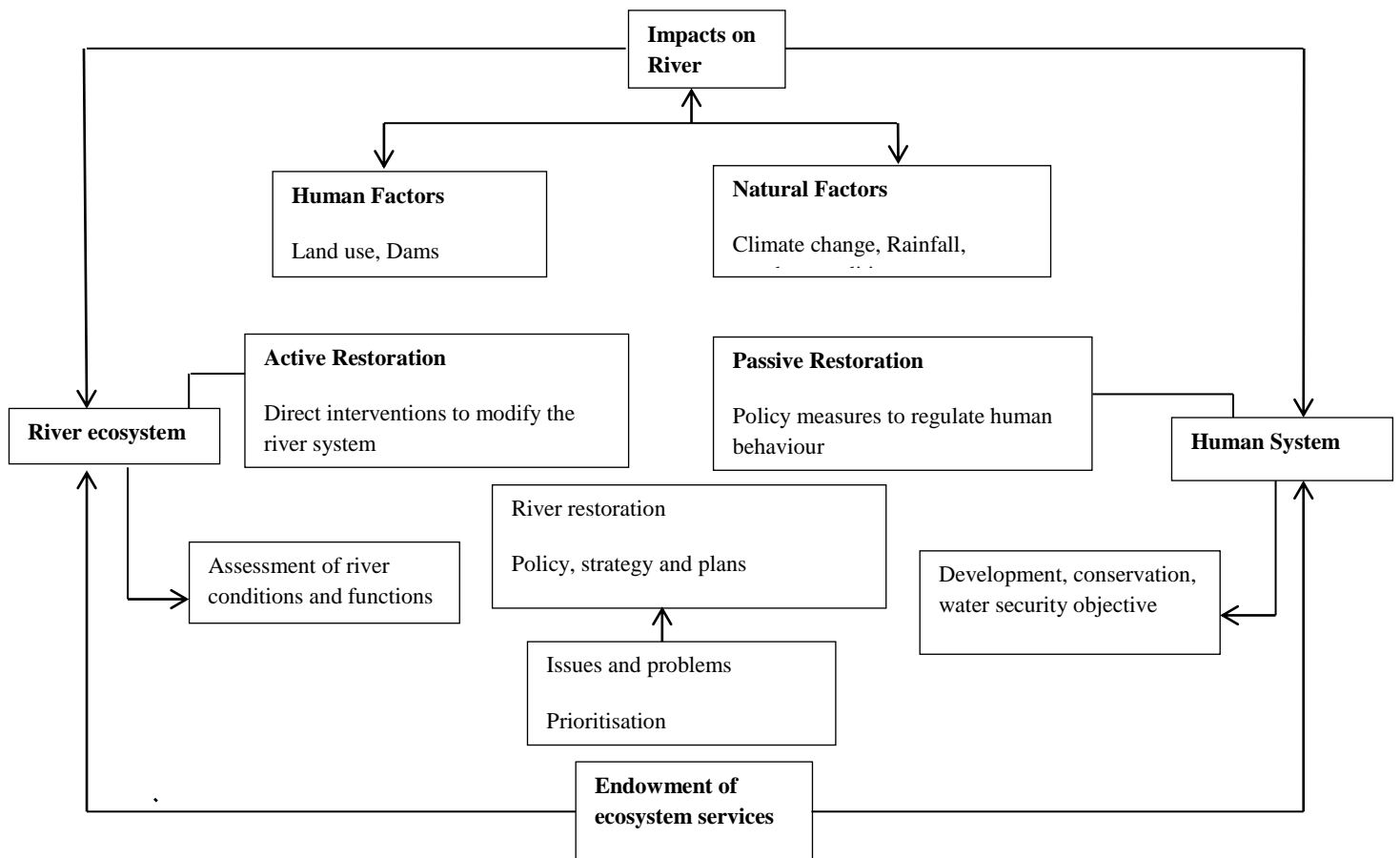
e) Partial and general Equilibrium Model

It's based on general equilibrium theory that combines behavioral assumptions with analysis of equilibrium conditions. It's an economic model that depends on supply and demand. It's used to predict the desired land types, especially in urban areas.

2.11 CONCEPTUAL FRAMEWORK

The Relationship between river restoration, river ecosystems and human systems

River restoration action is determined by two major factors, degradation of the ecosystem such as through abstraction of water and the loss of services offered by the river. Restoration and rehabilitation of the river are necessary as rivers have crucial roles in both the natural environment and human environment. They act as habitat for species where they live, reproduce and eat, it acts as a barrier and conduit as they allow movement and transportation corridor of materials and energy, source of sink, food, source of water for drinking and irrigation, cultural and spiritual rites, flood attenuation and source of sediment(sand for construction) (McCully, 2001). Most of the freshwater is used for agriculture via abstraction which is approximately done at the rate of 75% (Carpenter et al., 2011). Without effective measures and policies, river water withdrawal by agriculture will rise by nearly 50% by 2030 (Water Resources Group 2030, 2009).



Author: Own source

III. Area of Study

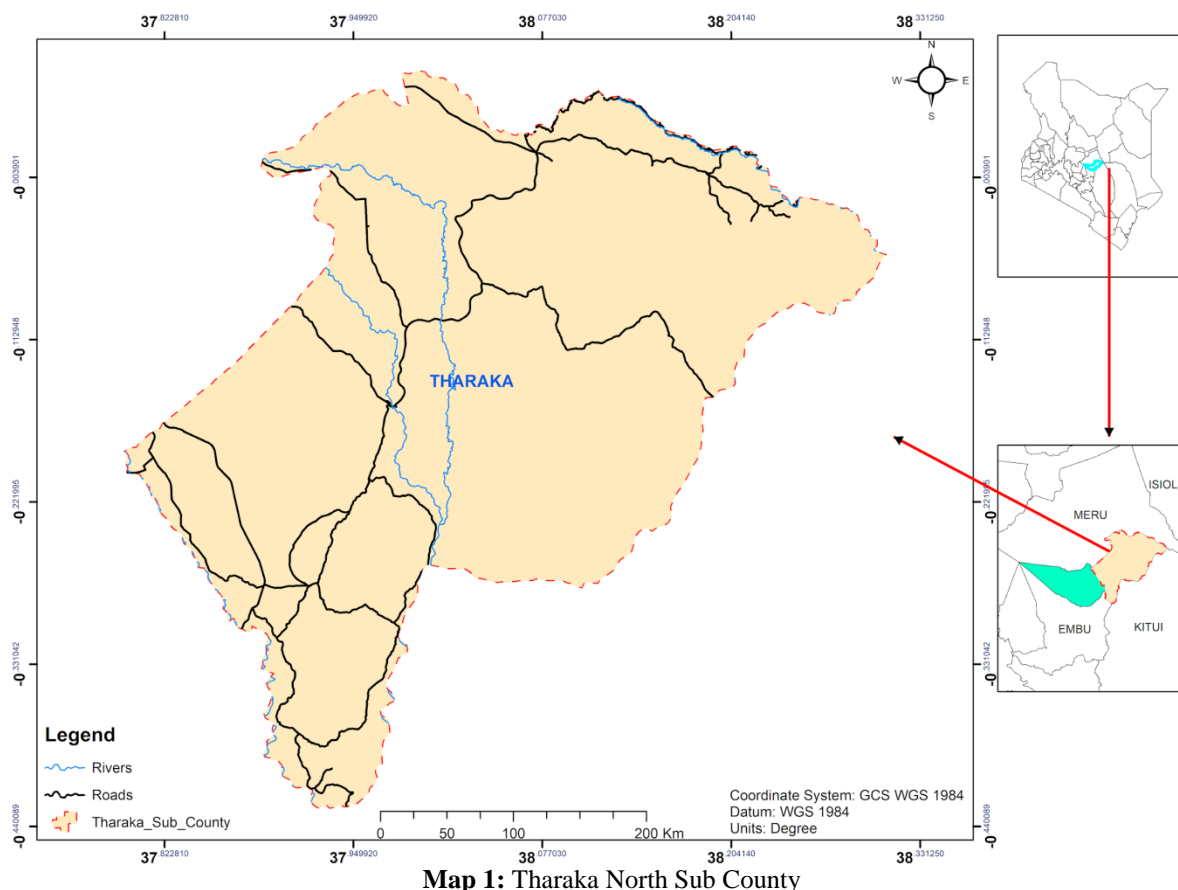
3.1 INTRODUCTION

The chapter entails background information about Tharaka North in terms of its location, Physical set-up (which is the geology, topography, drainage, climate, and soil), Economic set up (composed of agriculture, transport, tourism, trade, and commerce) and social set up (composed of demography, population projection and population composition)

3.2 PHYSICAL SET UP

3.2.1 Location and extent

Tharaka-North Sub County is located in former Kenya's Eastern Province and lies between latitude 0°06'03.31''S and longitudes 38°00'30.34''E. It is one of the three Sub Counties in Tharaka Constituency and has two wards; Mukothima and Gatunga wards. Tharaka North Sub County has an area of 803.4km² and a population of 49,976 (KNBS projection, 2013). It's bordered by Meru County on the North, Kitui on the East and Embu on the South.



Map 1: Tharaka North Sub County

3.2.2 Topography and drainage

The drainage system in Tharaka North Sub County is composed mainly of three rivers Ura, Thanantu, and Thangatha whose source is the Mt. Kenya and they drain into River Tana.

3.2.3 Soil and geology

The area is covered by thin sandy soil overlying rocks of the metamorphic rocks system and granitoid gneisses which is most evident in seasonal streams. The Precambrian rocks covered by sandy soil due to the support of vegetation such as shrubs, grass, acacia trees and other forms of vegetation are predominantly found in the area. The rocks occur as folded and fractured gneisses and schists with all forms of weathering and in some cases form very steep hills. Geology of the area determines the velocity, turbidity and the mineral content of the river.

3.2.4 Climate

The Sub County is a semi-arid area with rainfall ranging between 200mm and 800mm. The area experiences short rains in the month of October to December and long rains in the months of March to May. The temperature varies from 35°C to 16°C.

The present climatically environment is being affected by climate change which is resulting from factors such as the human. Therefore, these changes have affected both climatic and rainfall patterns of the area.

The area receives low and unreliable rainfall due to the low altitude and high temperatures, therefore, resulting in low water volumes in the river.

3.3 ECONOMIC SET-UP

3.3.1 Agriculture

In the area, agriculture is the dominant economic activity whereby it includes growing of millet, sorghum, maize, cotton, green grams, cowpeas, peas, cassava, vegetables and fruits such as mangoes.

The residents also are pastoralist whereby they keep animals such as cattle, goats, and sheep which are the source of income especially for fees and during drought seasons.

They are practice beekeeping which generates income for the farmers. The honey is sold mostly locally through farmer-farmer trade and also to suppliers who sell in supermarkets. E.g. Tharaka Honey.

The agricultural activities cause pollution of the river thus affecting the water flow and quality due to sedimentation, irrigation, soil pollution and fertilizers to the river from land uses. When the soils from farms are washed into the river during the rainy season, they cause siltation in the river resulting in flooding.

3.3.2 Trade

Tharaka North Subcounty has trading centers located at Gatunga, Kathangacini, Mukothima, and Gatithini. The trading centres are dominated by retail and wholesale shops, Open hair market. These trading centers are involved in the sale of food products mostly being cereals, fruits, vegetables, attires, and livestock.

The residents sell charcoal and timber for income whereby charcoal burning has become a dominant substitute of crops as a source of income.

Trading centres contribute to the turbidity of the river due to poor waste management. Gatunga and Mukothima markets lie next to Thanantu River.

3.3.3 Tourism

The rivers flowing from Mt. Kenya are the lifeline for major tourism destination areas including Meru National Park (Ura Gate) and Gaciongo Tourism Site which is a rock covered area, giving site view of the whole of Tharaka Constituency. The Sub County is endorsed by physical features like hills such as Gikiingo.

The tourism industry overuses water resources in for hotels and personal use of water by the tourists. This can result in water shortages and degradation of rivers. The industry may result in pollution of the river due to waste disposal and sand harvesting.

3.3.4 Education

The educational institutions in Tharaka North Sub County are and will collaborate in the achievement of the objective of the study since they create common avenues that allow the creation of awareness on sustainable river catchment management.

3.4 SOCIAL SET UP

3.4.1 Land uses

The area has several land uses which include: Transport, Agriculture, Industrial and Commercial whereby Agriculture is the most dominant land use with small-scale farms at 2.9 ha and large-scale farms at 6.7 ha. The industries found in the area are Light industries and several commercial centers are evident in the area with different kind of commercial activities.

These land uses have negative impacts on Thanantu River as they pollute the water and outflows due to their activities are more than the inflow. Therefore, resulting in low water levels.

3.4.2 Infrastructure

The main transport network to Tharaka North is the Ishiara-Ciakariga-Gatunga road which is currently under development. The rest of the sub-county (from Gatunga) is accessed by a number of earth roads. Most of the area is within the network coverage for mobile phones providing a reliable means of communication and with Faiba installation being undertaken presently.

Construction may lead to land degradation which results in deforestation, therefore enhancing river pollution through increased runoff and erosion.

3.4.3 Administration

The Sub County covers an area of 803.4 Km² and it's administered by Sub County Commissioner whose office is situated at Gatunga. The area houses other administration offices too such as Police Post, Chief's Camp, Education offices, and Agriculture. It has two wards; Mukothima and Gatue.

The administration units play a vital role in the conservation and management of Thanantu River.

3.4.4 Economic Condition and Livelihood Activities

In the area, the Small-scale and medium scale businesses are the main economic activities i.e. retail and wholesale shops, bars, hotels and open-air market.

The most of the people generate their income from; Sale of food crops such as cereals in the market and homes, Sale of livestock and their products, casual laboring, Small-scale retail and wholesale businesses and Formal employment.

3.4.5 Energy Source

Most of the area residents depend on traditional fuels such as charcoal, Paraffin, Maize Stalks, Sawdust and Fuelwood as their main source of energy while a few use solar energy, electricity, stove and gas cookers. Most depend on wood fuel and charcoal as electricity only covers a few households and trading centers. There has been an increase in the use of solar energy as the main source of energy over the recent past.

This has resulted in deforestation along the river thus more evaporation taking place which reduces water flow.

3.4.6 Health

The most common diseases in Tharaka North are malaria, diarrhea and dysentery and all are water-related diseases. It has a network of health facilities: sub-district hospital, Dispensaries, Health Centers, medical clinics and other private facilities. These facilities aid in treating of water-related diseases especially those living near Thanantu River and using its water.

IV. Methodology

4.1 INTRODUCTION

The Chapter represents data sampling techniques, collection methods, analysis, and interpretation.

The methodology is the systematic, theoretical analysis of the methods applied to the field of study (Donald et al., 2018).

The research aimed at identifying issues related to encroachment of water resources by land uses within the basin, in this case, it focused on River Thanantu and on what has been done, being done or could be done to ensure river's restoration, protection and proper management for its sustainability.

4.2 RESEARCH DESIGN

Research design provides a plan to be used in data collection, analyzation, and interpretation in regard to the accomplishment of study objectives (Daniel & Aroma, 2011). It's important as it provides systematic observation of the research questions. The study adopted Correlation and descriptive research designs.

4.2.1 Correlation research design

Correlation research design is used to determine whether or not two variables are correlated. This is whereby an increase or decrease of one variable corresponds to an increase or decrease in the other variable (Robert et al., 2017).

This design was used to show the relationship between land uses, land use changes and River Thanantu ecosystem/catchment.

Types of Correlation

There are three major categories of correlations.

a) Positive correlation.

This is established between two variables whereby an increase in one variable leads to an increase in the other while a decrease in one leads to a decrease in the other variable.

b) Negative Correlation.

Is when an increase in one variable leads to a decrease in the other and a decrease in one variable lead to an increase in the other.

c) No Correlation.

This is when two variables are uncorrelated which means a change in one doesn't affect the other.

Why the study opted for correlation design

The research adopted correlation design to gain quantitative data and show the strength of land uses, land use changes and River Thanantu. This shows how they have impacted one another, their relation, dependency, and independence.

4.2.2 Descriptive Research Design

The design provides answers to questions of who, what, when, where and how it's associated with the research problem. It's used in acquiring information concerning the current status of the phenomena and what exists in regard to variables (Lisa, 2007). It involves:

a) Observation- viewing and recording the participants.

b) Case study- an in-depth study of individuals

c) Survey- discussion with individuals about a specific topic

The design is used because of its:

- i. Collects adequate data for detailed analysis.
- ii. Yields rich data that led to important and relevant recommendations
- iii. Is effective to analyse non-quantified topics and issues.

Why adopt description design in the study

The design was used to show the current and previous status of both the land uses and river Thanantu in Tharaka North Sub County.

4.3 NATURE AND SOURCES OF DATA

So as to achieve the objective of the study, both primary and secondary data were used. The primary data were collected through the administration of questionnaires, observations, and interviews while secondary data was done from books and internet sources.

There are two main types of descriptive data; the Qualitative and Quantitative data. Qualitative data is that data that cannot be measured (Joseph, 2012) while the Quantitative data is that data that can be measured, counted and can mathematically be analyzed (John, 2014).

Table 3: Objectives, nature, sources and type of data

Objective	Data	Type Of Data	Sources
To establish land uses up to last 15 years in Tharaka North Sub County	Land tenure Land Use Types Farm acreage Activities Distance	Qualitative, Quantitative and Correlation	Ministry of Lands, Residents
To establish the effects of land use changes on Thanantu River.	Water quantity Causes, Impacts and challenges of water fluctuation River Thanantu changes	Qualitative and Quantitative	Interviews with the residents, Ministry of Agriculture, Ministry of Environment, WRUA
To determine strategies and efforts in place in Thanantu river restoration and alternatives in place due to its fluctuation.	Restoration mechanism Public participation Alternative water sources Policies, legislation and Institutions	Qualitative	WRA, Residents, Ministry of Agriculture, WRUA

4.4 DATA COLLECTION INSTRUMENTS

4.4.1 Primary Data

Primary data was collected during the study through observations and direct communication with the respondents. The methods that were used are;

Table 4: Data collection instruments and descriptions

Instrument	Description
Questionnaires	Contained questions on land use and river water management and were administered to different people within the River Thanantu ecosystem. It was done in households. They contained questions on coping mechanisms by individuals and restoration mechanisms, their water sources, type of land use they practices and their location, the previous land uses.
Interview schedule	This was achieved via asking a different kind of questions depending on the needed information in a face to face situation. This was used in institutions to acquire information on river restoration mechanisms, the operating policies and institutions and information on land uses both present and past.
Observation	Was based on various activities within the river and its vicinity. Will be through the use of a checklist about the status of river Thanantu, the land uses within the river basin at a radius of 100m and any alternatives or coping mechanism.
Photography	Data was collected by taking of photographs to show various activities, the condition of the river, to show a clear study area and contributions of the activities to the reduction of the river ecosystem.

4.4.2 Secondary Data

Secondary sources of data were collected from journals, state of environment reports, books, other published information and online sources, topographical map and satellite imagery to show the difference in river ecosystem over a period of time. This data played role in the establishment of what has been done, being done in the rehabilitation of the river and to be done.

4.5 POPULATION DESCRIPTION

Tharaka North Sub-County has a population of 49,976 occupying an 824 sq. km piece of land. The target population will include government agencies; Community based organizations, individuals, and households who have interest in Thanantu river ecosystem and basin. The views from individuals and groups will be included in the report on their take on River ecosystem management. Their views will also be used in drawing of recommendations and ways in which river ecosystem and basin can be reclaimed and managed sustainably.

4.6 SAMPLING METHOD

4.6.1 Systematic Random Sampling

The systematic random sampling method was used in data collection. This was done only on those who live around and along the river basin and those that have encroached it through land uses. This was done at a gap of 10 households.

4.6.2 Purposive Random Sampling

This sampling method was used in the selection of knowledgeable people on the research topic who were very resourceful to the study. These included government officials/institutions and the elderly as they have the required information and relevant to the study. Purposive sampling was deployed as the researcher can select a sample which serves the study's purpose.

4.6.3 Sample size

The sample size was calculated using the Cochran formula (Sigh, 2014) which is suitable for a large population. This was so as the study area was large with a large population.

Sample size= distribution of 50%
The Margin of Error%
Confidence level score 2
True sample= (sample size*population)
(Sample size+population-1)
Population is 49, 976
Therefore;
 $(0.5*(1-0.5) = 0.25$
 $(0.05/1.96)^2 = 0.00065077$
 $= 384.16$
 $(384.16*49976)$
 $(384.16+49976-1)$
 $= 381.237$ Approximately Sample size is 381

Simple systematic formula

$K=N/n$

K is Number of Households

N is Sample Size

n is the interval

Therefore,

$K= 381(\text{sample size})/10(\text{interval}) = 38.1$ Therefore: **38 households.**

The equation above is used to calculate sample size which is further divided by 10 (using Simple Systematic formula) to come up with the number of households. This is so as the study adopted systematic sampling of interval 10.

4.7 METHOD OF DATA COLLECTION

Data was collected through the following methods;

- i. Administering of Questionnaires on a sample of household and businesspersons in the areas of study.
- ii. Interviews with different institution representatives.
- iii. Surveys and observations.
- iv. Photographs.
- v. Reviewing the existing literature and published materials

4.8 DATA ANALYSIS

After data collection, the questionnaires were sorted into categories of coded and random whereby analysis, interpretation, and recommendations in accordance with research objectives were done. The data was represented by the use of bar charts, pie charts, and tables.

4.9 CONSTRAINS TO DATA COLLECTION

During the data collection there were a number of challenges faced:

- a) Inaccessibility of some areas of interest for the research.
- b) Financial constraints- inadequate funds for movement around the study area and high printing expenses.
- c) A large area of coverage- The area of study was large for coverage with some areas having less or no impact on the variable, therefore, making the larger part of the Sub County irrelevant to the research.

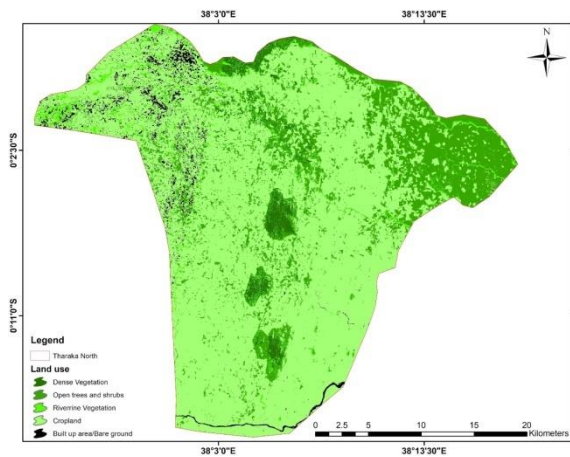
V. Findings, Results and Discussion

5.1 INTRODUCTION

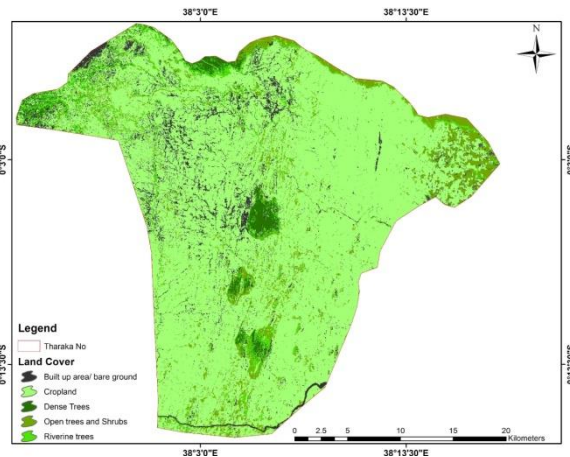
The main purpose of the study was to find out land trends in Tharaka North Sub County, their effects on River Thanantu, activities carried out in the river, the contribution of locals and institutions on management, conservation, and protection of River Thanantu and Alternative water sources. Therefore, the overall goal of the study was to find out the effects of land use changes on River Thanantu. It was carried out in Tharaka North Sub County through the administration of questionnaires and interviewing only those residing next to the river and to institutions within the Sub County. This chapter analysis the data collected, analyzed and inferences made through the procedures outlined in chapter three. Findings, analysis, and discussions are presented in accordance with objectives.

5.2 LAND USE TRENDS IN THARAKA NORTH SUB COUNTY

The study identified the land use trends in Tharaka North both the current, previous and the land use that was in the area in the last 15 years.



Map 4: Year 2002



Map 5: Year 2017

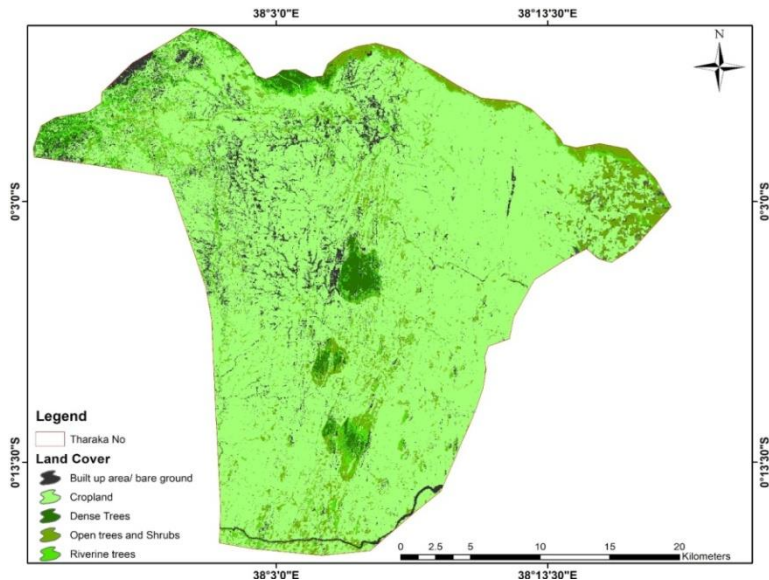
Initially, the land in the area was communally owned up to Mau Mau Era and the 1952 -1964 ‘Shifters’ Era who were Somali people; locally known as *Cumari B*. They stole cattle and burnt Kathangacini market which was the cattle market in Tharaka. This led to the migration of people from the area to other areas of Tharaka North especially Gatunga and establishment of schools like Rwatha primary school. After this era, people started owning land through identification of land of interest and creation of boundary on it as a symbol of ownership. This enabled them to acquire large pieces of forested land. Later on, they converted from pastoralists to mixed-farming (agriculturalists, pastoralists, and bee-keepers). Land adjudication process started in the 1980’s with most of the land being forested. This increased in settlements in the area together with other land uses

In the early 1980’s, the main land use in Tharaka North Sub County was a **pasture land** then later the Meru community converted the pasture land into **agricultural land**.

The Sub County had small trading centers mainly for livestock but now the trading centers have enlarged and more have been established.

There were no defined permanent residential use and institutions as they were mainly pastoralists but now there are permanent residents.

5.2.1 Current land uses



Map 2: Tharaka North Land uses as at 2017

Land uses within the area include; Agriculture, Commercial, Transportation, Industrial, and Institutional.

Agricultural land use

Agriculture is the main land use in the area with crop production as the mainstay of the local economy. The residents are both farmers and pastoralist. The area support growth of variety of crops such as maize, beans, sorghum, millet, green grams, cowpeas, peas and different kind of fruits. There was also the presence of

plantation such as mango tree plantations. Most of the farmers depend on rainfall water as their source of water in the farms and others irrigate their land.

The main crops grown are:

- a) CEREALS: Maize, Millet, Sorghum, Cassava
- b) LEGUMES: Beans, Peas, Cowpeas, Peas, Green grams
- c) VEGETABLES: Kales, Scallion
- d) FRUITS: Mango, Oranges, Bananas, Avocado,
- e) CASH CROPS: Cotton, Sunflower, Tobacco

The main animals kept are: Goats, Cattle, Donkey, Sheep

Some of the crops and animals are used for subsistence purpose while others are for commercial use.



Plate 1a: Agricultural land Use in Tharaka North Sub County



Plate 1b: Mango trees plantation- Agricultural Land use in Tharaka North Sub County

Residential land use

Most of the population reside in the area with sparse form of settlement and Bungalow type of housing.

Institution land use

The kinds of institutions found in the area include;

- a) SCHOOLS: Secondary both Day and Boarding, Primary both Public and private with Day and boarding
- b) ADMINISTRATION: Sub County Offices, Chief camps and Police post.
- c) HOSPITALS: District hospital and Dispensary

Commercial Land use

The residents practice a different kind of both retail and wholesale commercial activities. These include shops and market centers.

Transportation land use

The dominant means of transport is the road. The roads within the area are rough roads with the main road currently being tarmacked.



Plate 2: Gatunga-Marimanti road- Transportation Land Use

Industrial land use

The area has light industries which are mostly located in market centers. They include Slaughterhouses and Jua Kali industries. Optimal rural industrial land use provides a spatial foundation for sustainable development in rural areas.



Plate 3: Light Industrial land Use in Tharaka North Sub County

Forest land use

The area has forest characteristics with shrubs, grass, and bushes as the dominant vegetation cover. Tree species found in the area include:

Table 5: Tree species in Tharaka North Sub County

Botanical Name /English Name	Local Name
Acacia	<i>Mugaa</i>
Azadirachiraindica/Neem	<i>Muarubaine</i>
Palm	<i>Kirara</i>
Sycamore	<i>Mukuyu</i>
Baobab	<i>Muramba</i>
Terminaliabrownii	<i>Mururuku</i>
Meliavolkensii	<i>Mukau</i>
Croton megalocarpus	<i>Mukinduri</i>

The table above shows the tree species mostly found in Tharaka North. However the most common are Terminaliabrownii, Acacia, Neem, and shrubs. Along River Thanantu the tree species found at the bank are both planted and Natural. The planted include Neem while Natural species are mostly Mango, Tamarind and Palm Trees.

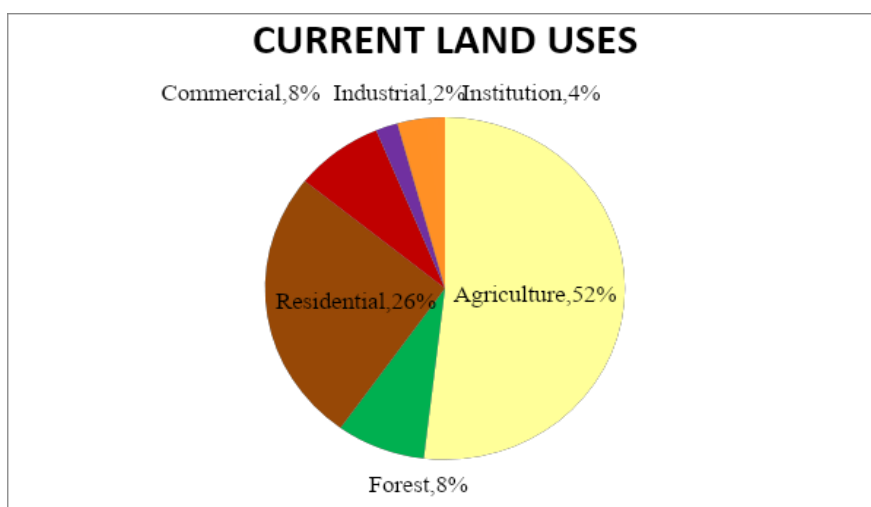


Figure 1: Current land uses in Tharaka North Sub County

5.2.2 Previous land uses

Previously land uses in the area were: Agriculture, Forest, Open space, Commercial and Residential. The dominant land use was the forest. This is so as most of the area was occupied by vegetation cover. These are the land uses that were there before the current one according to the respondent.

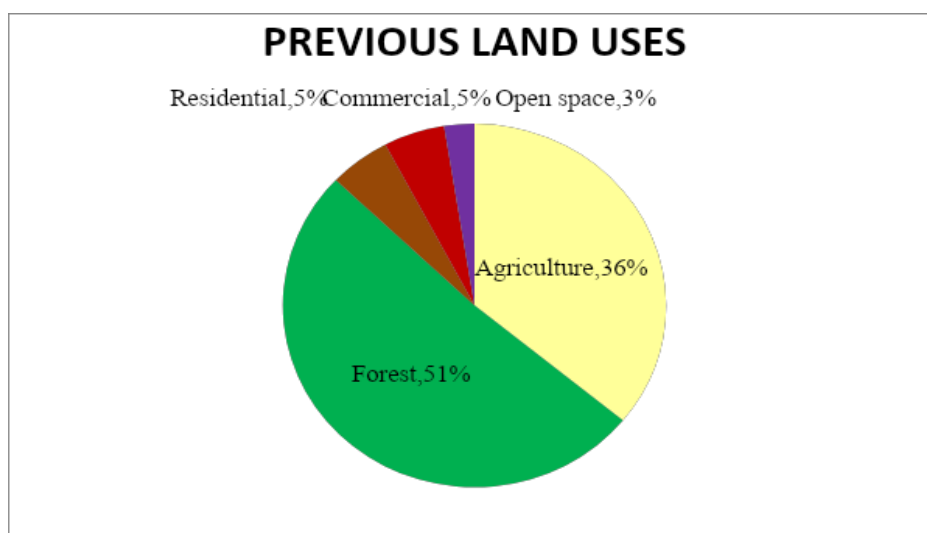
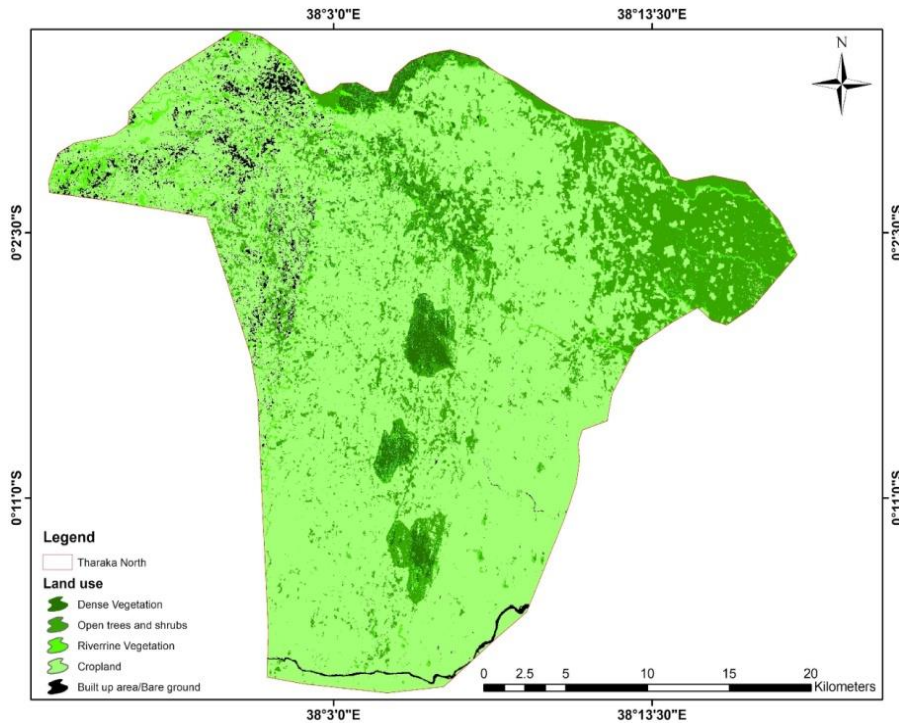


Figure 2: The previous land uses in Tharaka North Sub County

5.2.3 Land uses in the last 15 years

In the past years, the dominant land use was Forest and pasture land with very few people having permanent homesteads and part of the land being left bare while the rest was cultivated.



Map 3: Tharaka North Land Uses as of 2002

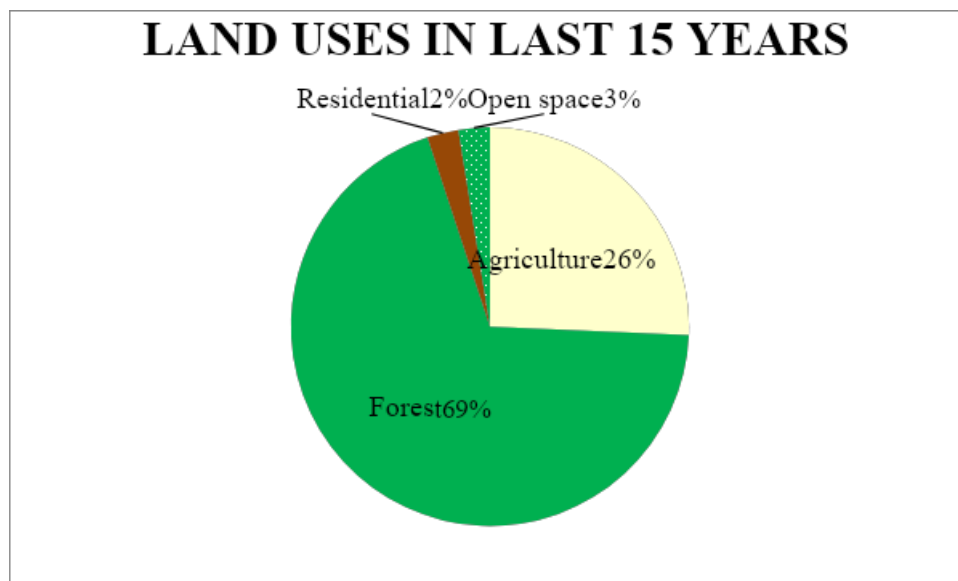


Figure 3: Tharaka North Sub County last 15 years land uses

5.2.4 Land tenure system

In the 1950's the land in Tharaka North was communally owned then later the people settled and owned the land. This led to changes in land uses from pasture land/ forest to others such as agriculture, residential

Most of the people own the land they live and carry out other activities; others have leased private land while others reside in the inherited land. The predominant land tenure system in the area is Private while public land is the subordinate. Therefore, the land tenure of the area includes; **Private land** (privately resided/ bought by the resident, leased or inherited) and **Public land**. There was no evidence of communal land. Most of the private land is leased to the interested party for farming.

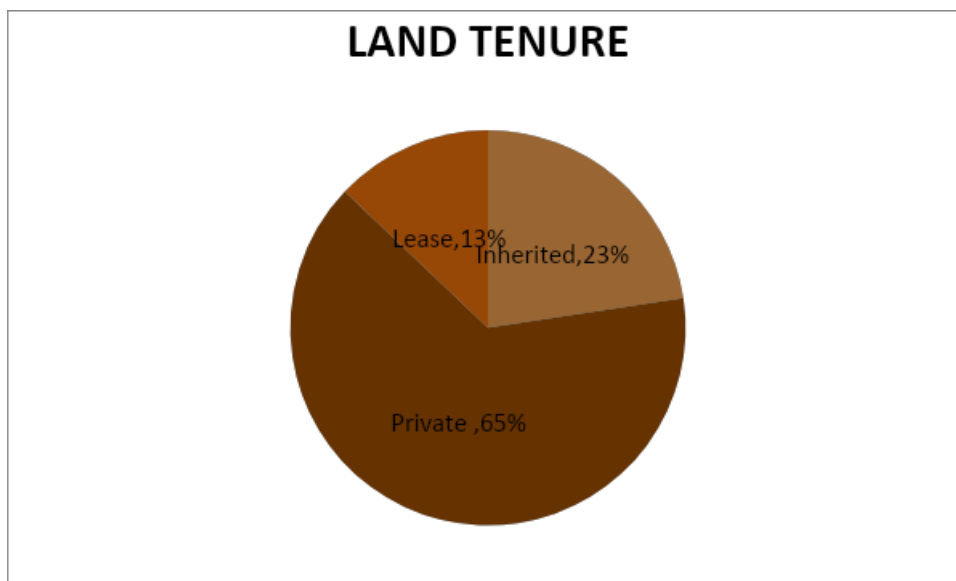


Figure 4: Land tenure system in Tharaka North Sub County

The study identified the farm acreage of the farms and their distance from River Thanantu. Majority of the representative population, own 1 to 3 acres of land which according to response was at 42% and the least being less than an acre which ranked at 9%. Privately owned have large pieces of land while those that have leased, have leased a small piece of land.

The farm holding size of small-scale farms is 2.9 ha while for large-scale farms is 6.7 ha.

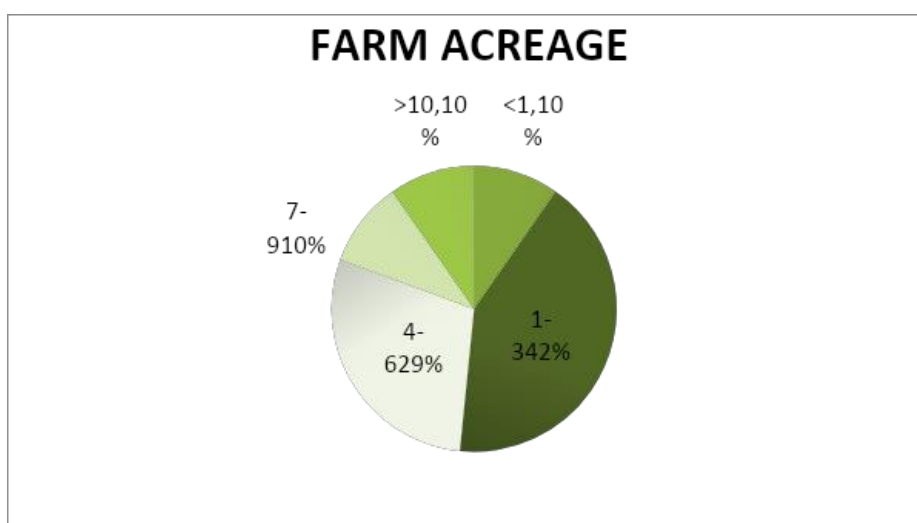


Figure 5: Farm acreage per household

There are different kinds of activities practiced in the farm/Land. These activities include:

- a) AGRICULTURAL: Grazing, Bee-Keeping, Farming
- b) LEARNING and ADMINISTRATION: Offices, Schools (Primary and Secondary)
- c) RESIDENTIAL: Rentals, Private
- d) COMMERCIAL: Market, Shops, Kiosks
- e) INDUSTRIAL: Light Industries such as Carpentry, Slaughterhouse, Welding, Jua Kali

Farming which includes crops and bee-keeping is the most practiced and common activity in the area while industrial is the least practiced. Most of the farms were 250M away from the river.

According to the research done, there's a positive correlation between the farm acreage and the distance between the farm and the river, farming duration and duration of residence. This means that as the farm acreage increases, the distance between the farm and the river, farming duration and residence duration increases too. Whereas, farm acreage and distance between home and the river have a negative correlation.

Thus, when farm acreage increases, the distance between home and river decreases. With the strong correlation, it means they both have an influence on each other and are dependent.

The distance between homes to the river has a strong negative correlation with the distance between the farm and river. This means that as the distance from home to river increases, the distance between the farm and river decreases.

Duration of residence and farming duration have a positive correlation with farm acreage. As the farm and residence duration increases it leads to increase farm acreage. Residence duration has a negative correlation with the distance between farms and river and distance between home and river. Therefore, an increase in residence duration leads to a decrease in distance between home, farm, and river.

Farming duration has a negative correlation with the distance between farm and river and distance between home and river. As farming duration increases, the distance between farm and river decreases as well as the distance between home and river.

Activity duration/ land use has a positive correlation with residence duration and farm acreage. Therefore, increase in activity duration leads to increase in residence duration as well as farm acreage, while activity duration has a negative correlation with the distance between home and river as well as the distance between farm and river. This increase in activity duration results to decrease in the two distances.

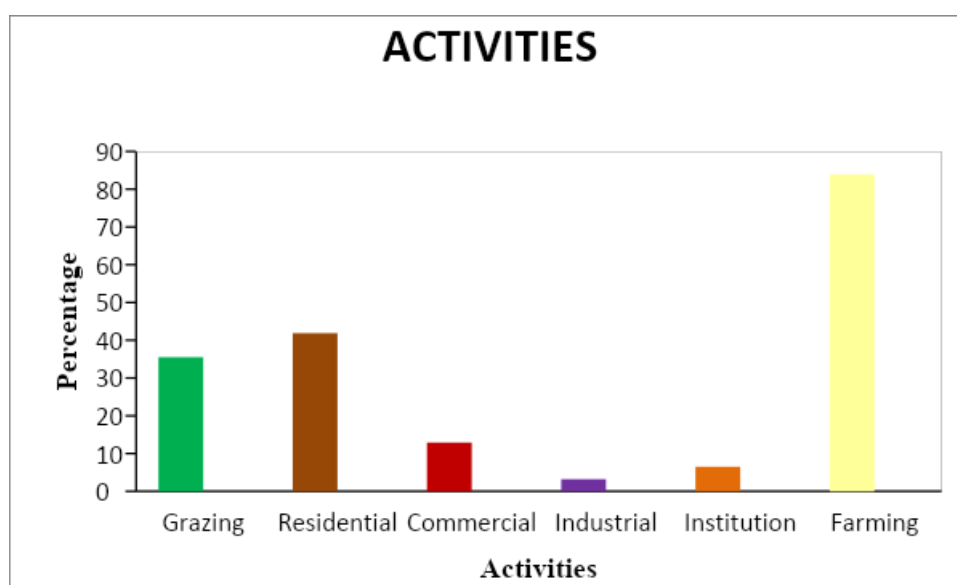


Figure 6: Activities in Tharaka North Sub County

5.2.5 Activities taking place along the River.

According to the study; farming, commercial centers, settlement, grazing, sand harvesting, water fetching, clothes and utensils cleaning, and logging were the main activities taking place within the river basin and were encroaching. Due to demand for food and settlement by the increasing population, the residents are and have encroached the river basin to provide more land for housing and agriculture.

These activities pose threats such as clearing of vegetation for fuel, housing, and commercial activities, loss of lives of aquatic animals, shrinking of the river channel, water fluctuation, and reduction in water level and dirtying of water making it unsuitable for consumption to the river.

These activities have inveigled changes that have eroded the socio-economic and ecological services derived from the river. This, therefore, has affected the quantity and quality of the products, value, and services of Thanantu River. The number of water sources have been declining as a result of human activities which includes; agricultural activities.

Table 6: Activities and their effects on Thanantu River

Activity	Effects
Farming	✓ Soil erosion which leads to siltation of Thanantu River.
	✓ Pollution of the water by pesticides, fertilizers, and herbicides used in the farms.
	✓ Abstraction, channeling, and obstructions reducing the water quantity and leading to the growth of fungus.
Grazing	✓ River bank erosion in cattle drinking points. This leads to deposition of sediments into the river which causes turbidity, therefore, affecting water quality.

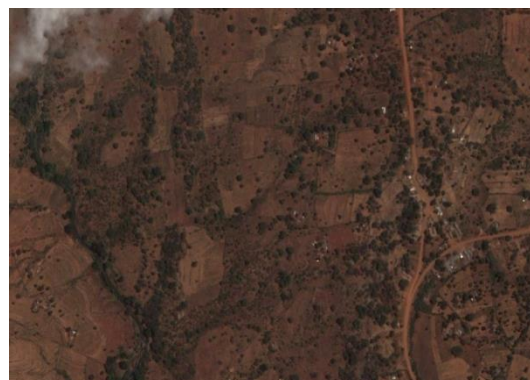
	<ul style="list-style-type: none"> ✓ Water pollution by animal waste. ✓ Reduction and clearance of vegetation.
Commercial centers	<ul style="list-style-type: none"> ✓ Elimination of trees and vegetation cover to pave way for commercial grounds.
Logging	<ul style="list-style-type: none"> ✓ Deforestation which leads to soil erosion. ✓ Reduction of fauna habitat found in the river ecosystem. ✓ Flooding of the river as there is no barrier.
Settlement	<ul style="list-style-type: none"> ✓ Vegetation clearance
Sand harvesting	<ul style="list-style-type: none"> ✓ River degradation through bank erosion. ✓ Reduction of riparian habitat, flora and fauna. ✓ Increases turbidity due to re-suspension of sediment. ✓ Water pollution due to oil leakage from the transportation vehicles.
Washing	<ul style="list-style-type: none"> ✓ Dirtying of water which makes the water quality poor. ✓ The growth of fungus as detergents provide nutrients for algae causing proliferation ✓ The soap is toxic substances which lead to death and migration of aquatics.
Industrial	<ul style="list-style-type: none"> ✓ Water pollution due to waste dumping.

Most of the farms near the river are at a distance of 250 meters from the river. The study used a systematic sampling method and chose a radius of 2km from Thanantu River. Closenesses of farms to the river have had effects on the river through the fertilizers, surface runoff and other effluents transported to the river from the farms.

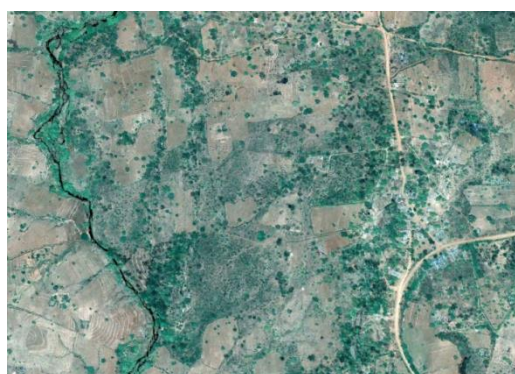
Land Use Trends In Tharaka North Sub County



MAP YEAR 2017



MAP YEAR 2010



MAP YEAR 2002

Tharaka North Sub County was majorly a forested and undeveloped land but with time the function has changed to agriculture, institution, transport, industrial and residential, with agriculture being the most practiced land use. The situation has been so due to the increase in demand for food production and having that agriculture is their main source of income, and the soils are favourable for farming. The type of land tenure and

land size determines what practice is and will be carried out on a certain piece of land depending on the preference of the owner.

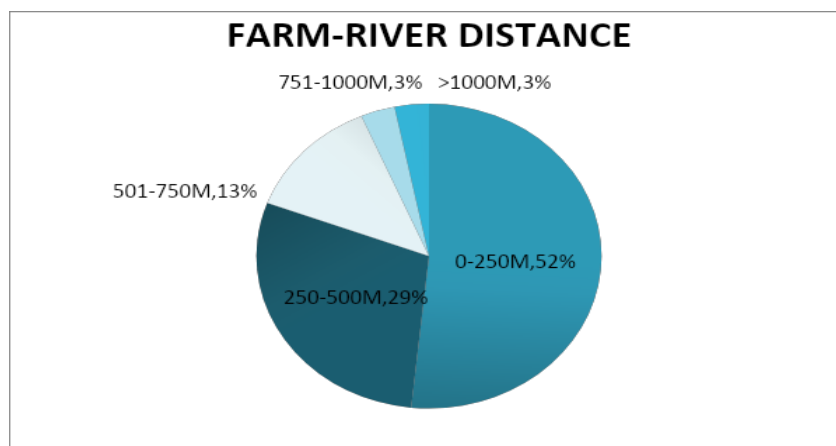


Figure 7: Distance between individual farm and Thanantu River

5.3 EFFECTS OF LAND USE CHANGES ON THANANTU RIVER

During the interview sessions, the effects of land use changes on Thanantu River was established and discussed. The issues looked upon were: land use effects on water quantity, status and changes in the river channel and ecosystem, their causes, impacts and challenges.

5.3.1 Water Quantity

From the research and observation, it was noted that the river has shrunk towards the middle and there's very minimal vegetation cover. This has affected the river water quantity making it unconducive for consumption and causing water stress to the area.

Over the last 15 years, Thanantu River has shrunk greatly, an incident which the respondents and locals attribute to encroachment by farms and expanding market, Clearing of trees for charcoal and fuelwood which are source of income to the residents, 1999 river overflow which swiped and uprooted most of the trees within Thanantu River basin and water abstraction for irrigation especially during dry seasons and due to inadequate rainfall.

There is a water level variation during different seasons. During the wet season, the level is high (above the normal stage and difficult to handle) and other times medium-high (higher than normal and faster flowing on a gentle gradient). This is so due to, sufficient rainfall and minimal or no water being drowned from the river for irrigation. During farm weeding and crop spraying season, the water level varies between high, medium (normal river flow with enough gradient) and low (below normal or drying up) due to channeling into the farms. During crop harvesting season the water varies between medium and low due to farm water channeling and abstraction while during the dry season it varies between medium and low. In the dry season, the level is mostly low which is attributed to No rainfall which leads to the abstraction of water for irrigation in fulfilment of food production demand.

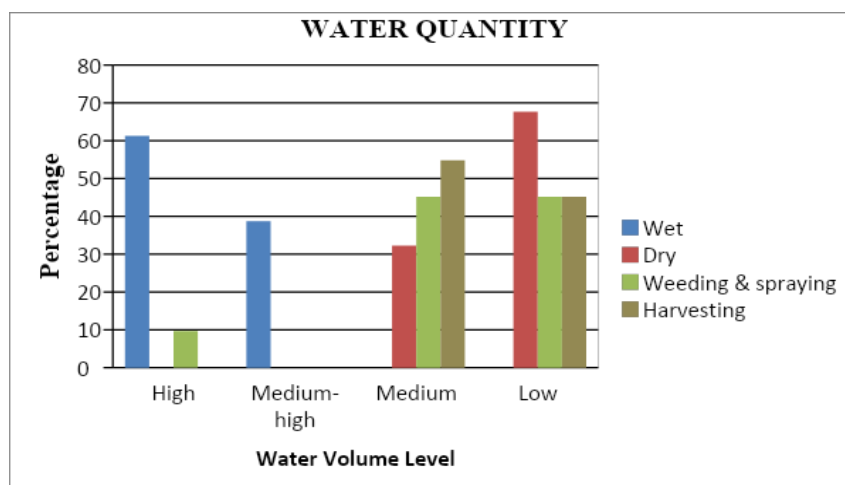


Figure 8: Thanantu River water quality



Plate 4: Water channeling

The river is most turbid during the wet season and clears during dry seasons. However, during the dry season, there is the presence of fungi and solid waste. The solid waste is mostly dumped into the river during Market days. During the weeding and spraying season, the water is turbid due to the presence of sediments deposition into the river from farms and contamination of water by fertilizers, herbicides and pesticides. The water is turbid during harvesting season due to sediment deposition from the farms.

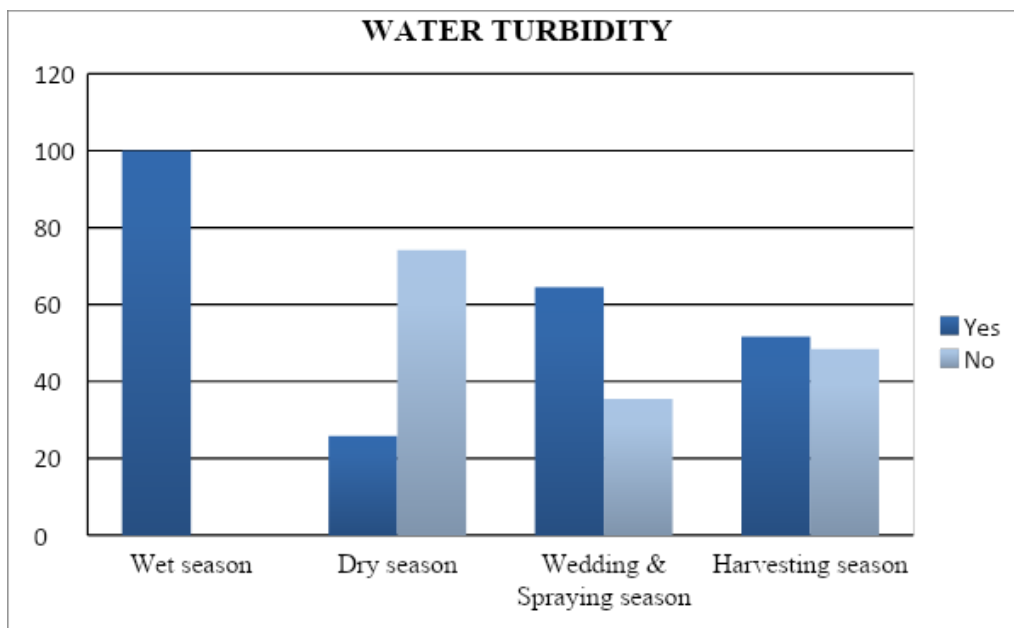


Figure 9: Thanantu River water turbidity during various seasons

From the respondents, the current water volume of Thanatu River is inadequate and therefore incurring water shortage while in the last 15 years it was adequate. The current situation has been caused due to climate change, deforestation, abstraction especially by the upstream residents, obstruction to homes and farms and insufficient rainfall.

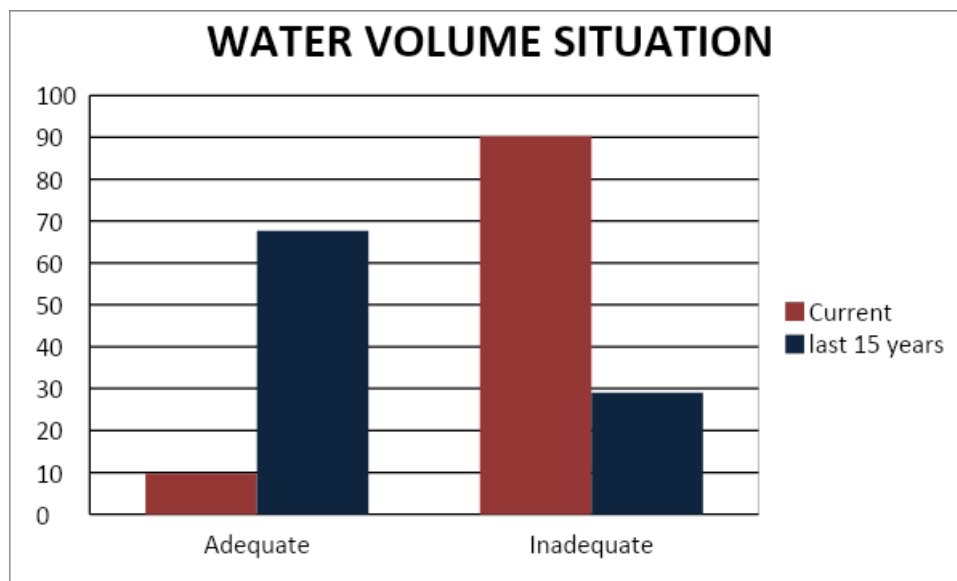


Figure 10: Current and Past water volume adequacy of Thanantu River

5.3.2 Causes of Thanantu River discharge fluctuation

The household survey carried out along Thanantu River in Tharaka North Sub County came up with the following causes of Thanantu River water fluctuations:

1. Natural Factors.

Natural agencies have highly contributed to water fluctuations in Thanantu River. These include;

a) Precipitation/ Rainfall.

Heavy rains cause saturation of the soil and hence lead to an increase in runoff which increases river velocity while low rainfall reduces river velocity. Tharaka North Sub County is a semi-arid area and lowest zone of Tharaka-Nithi County and receives low, unreliable and poorly distributed rainfall of less than 1000mm per annum. The low and unreliable rainfall has caused water fluctuation in Thanantu River. During the dry season, there's little or no water in the river whereby the locals end up 'digging wells' on its bend.

b) Temperature

The area experiences temperatures of ranges between 26⁰C and 40⁰C. Analysis of temperatures in the last 25 years shows that first and second season mean temperatures have increased by 0.7 and 0.5⁰C respectively. This rise in temperatures during the dry spell results to increase in evaporation which affects Thanantu river discharge.

c) Runoff

Surface runoff is important as it keeps rivers full of water which influences river discharge. During the rainy season, there's surface runoff whereby the water runs into the river when the land surface is saturated. This increases water discharge in the river. During the dry season, the discharge declines as there's no water flowing into the river.

Tharaka North Sub County has prolonged dry seasons and therefore affecting Thanantu River discharge. During the rainy seasons, there's increase in discharge while during the dry season the discharge declines.

2. Unregulated outflows

Over withdrawal of river water cause decline in the water table thus decreasing its discharge. These withdrawals are done through both illegal and legal abstractions and obstructions for irrigation purpose and other uses by the locals.

This action of unsustainable withdrawal has caused Thanantu River discharge fluctuation as outflows from the river are faster than replenishment of the river. The locals from both Tharaka North and neighbouring County (Meru County) carry out abstraction of Thanantu River water for irrigation purpose and domestic use. Those living on the downstream side of the river have access to less water than those on the upstream side. This is a result of abstractions by the upstream locals. Tharaka North Sub County, Thanantu River has 8 abstraction points. This has reduced its water especially during the dry season (which is the longest season in the region) to the extent it's drying up. It has greatly contributed to drought and hunger experienced in Tharaka North Sub County. Within the same Sub County, it was found out that, the river has more water in Mukothima Ward than Gatunga Ward.

3. Climate Change

As the earth's temperatures increases, there's a significant impact on the water sources especially the rivers. Climate change has effects on water quality and intensity of precipitation. Rising temperatures cause more precipitation to fall as rain rather than snow, therefore, reducing reservoirs that feed the rivers during dry seasons.

Climate change increases water demand while shrinking water supplies. It interferes with the water cycle (precipitation, evaporation, infiltration). High temperatures increase the rate of evaporation into the atmosphere. It results in changes in rainfall patterns and melts in the snow. The melted snow runs into the river increasing its discharge. At the same time, it may result in rains which increase river discharge and other times prolonged dry seasons which leads to drying up of the river. Rise in temperatures results to increase in water demand by both animals and people and increase in evaporation which may result to drought.

Climate Change has resulted in the fluctuation in Thanantu River discharge as the amount of water demanded by the people exceeds the inflow and the rate of evaporation is higher than past years. It has also resulted to melting of snow at Mt. Kenya which means that Thanantu River loses its water sources. This has contributed to the water shortage and stress experienced in the region.

4. Human factors

Human factors such as deforestation and poor farming have impacts on river discharge. The deforested areas cannot hold rainwater which runs down into the river and may cause flooding in the lower areas. Where the river turns, the water could cut its bank, change its shape and channel and destroy nearby properties. Thanantu River originated from Mt. Kenya and there has been deforestation along the river and in Mt. Kenya Forest. The action is due to demand for fuelwood, charcoal, and timber for both commercial use and subsistence. Therefore, during the rainy season, there's more water in the river as there are less or no barriers.

Poor farming practices such as inappropriate irrigation and over-drafting have caused discharge fluctuation of Thanantu River.

5. Population growth

Increase in population means more demand for food and other activities. Increase in population has resulted to increase in water withdrawal from Thanantu River so as to meet the need of food production and other needs that need water as it's the main source of water in the region.

The population is highly correlated with water supply, therefore, as population increases there will be significant water shortage as Thanantu River will dry up.

6. Increased frequency of drought

Climate change has resulted in increased incidence of droughts which have greatly diminished Thanantu River discharge as people try to curb this problem. The locals end up using water from the river unsustainably and excessively for agriculture so as to deal with drought issues.

5.3.3 Challenges associated with Thanantu River discharge decline.

The respondents highlighted both long term and short term challenges they encounter due to Thanantu River discharge fluctuation. They included:

1. Water stress/ shortage

Thanantu River is a permanent river in the area and the locals highly depend on it. Due to the decline in its discharge, they have to live with lack of access to adequate water for consumption and agricultural purposes. 90% said that the water from Thanantu was inadequate while 10% indicated that it was adequate. The Kibuka dam construction is to foresee this issue in Tharaka South, Tharaka Central and Tharaka North Sub Counties. It's purposed to boost the Galana project in aid of ending food scarcity in the County and nation at large.

2. Food Shortage

The main resident's income generator and activity is agriculture. Having the area experiences low and insufficient rainfall, they depend on water from Thanantu River for irrigation/agriculture. Due to its decline, the area has been experiencing drought and hunger as food production quantity has gone down and can't keep up with the demand. This has resulted in most of the locals migrating to other counties in search of food for their families.

35% of the population incur a shortage in both commercial and subsistence food while 30% have enough subsistence and commercial food. 17% incur shortage in commercial food with enough subsistence while 24% incur shortage in subsistence food with enough for commercial. This Index, therefore, indicates food shortage in the area. Therefore, 21% of food production in Tharaka North Sub County is used in households while 31% is for commercial purposes.

The poor harvest of food crop and livestock production has led to high crop price rise thus resulting in food insecurity in the area.

Intra- migrations of livestock from Kathangacini, Kanjoro and Ntoroni locations of Tharaka North Sub County to Meru National Park, is a common trend in the periods of drought. This further has reduced milk production and consumption per household from 1.5 litres of production to 0.72 litres and 1 litre of consumption to 0.65 litres.

3. Waterborne disease

Water fluctuation comes along with sanitation issues exposing the locals to diseases such as cholera. The region is prone to cholera and typhoid when Thanantu River discharge declines to extent of drying. In a year at least 29 people are diagnosed with cholera in Tharaka North Sub County. This is so as only 50% of the households use treated water, leaving the rest exposed to waterborne diseases.

4. Loss of flora and fauna

Thanantu River depletion comes handy with loss of flora and fauna. The decline in water and drying up of the river means reduced habitat for aquatic species leading to loss of biodiversity and their reduction. 80% of the land in Tharaka North Sub County is arable land/ under agriculture. This means that more land has been cultivated leading to loss of flora and encroachment of the Thanantu River riparian.

5. Water Use Conflict

Water use conflict arises due to the different interests of both private and public water users. Thanantu River is shared by two Counties; Tharaka-Nithi and Meru Counties. Over-withdrawal by locals from Meru County has contributed to the depletion of Thanantu River. This has led to conflict between the two communities as the locals from Tharaka North have access to no or little water from the river.

The upstream water users overwithdraw for irrigation purposes. The downstream users have to endure with less or no water from the river due to this overwithdrawal by the upstream users. This has resulted in conflict between downstream users due to competition. There has been a conflict between the water users and the government. The laws enforced aren't adhered to and the users feel they are irrelevant and too much, as they restrict them from using the river water and ecosystem to their liking.'

A conflict between authorities and users due to the enforcement of laws.

6. Economic slowdown

There's economic slowdown in Tharaka North Sub County due to food shortage. Their main source of income for the local is agriculture which depends on Thanantu River water. Therefore the decline in its water means low food production thus economy retardation. The river is used for irrigation purposes which boosts the economy of the people and county at large. With decline in its discharge, the surplus is low. The low surplus is used for subsistence purpose instead of commercial, therefore, leading to economic shutdown.

5.3.4 Changes in Thanantu River ecosystem and their causes.

Thanantu River has undergone changes together with its ecosystem. These changes include:

1) Reduction in vegetation cover.

Vegetation cover that was initially at the river basin has declined with some parts having none. The vegetation cover Index shows a depicted vegetation cover at index 48 compared to 59 of the previous year.

This has been caused by the intensive grazing of livestock on the vegetation cover. As the animals drink water from the river, they feed on the vegetation cover while some herders literally graze their animals along the river. This has led to declining in vegetation cover. During the dry season when the pasture has declined, the livestock are grazed along the river.

Clearance of vegetation has been influenced by the increase in population. Over the years the population in the area has increased leading to more land demand for settlement and agriculture. Therefore, the riparian area has been invaded and cultivated as its considered fertile favouring crop production.

The people have commercialized trees as they bring income in form of charcoal, timber, posts, and fuelwood. Others use the same trees for settlement establishment. This has resulted in the cutting down of trees along the river as most of the trees are fit for timber and posts production while others burn and bury them for charcoal production. Having the main source of energy in the area is fuelwood and charcoal; it makes the trees prone to deforestation, whereby it's both an income generator and need.

2) Shrinking of the River channel.

The river channel has shrunk with water only flowing in the middle on the downstream. The downstream the river flows, the lesser the river channel depth and width, therefore, the less the water. Unmanaged outflows and low rainfall has led to declining in river discharge which has led to shrinking of the river channel.

Table 7: River Thanantu channel

Gradient	Length(m)	Average channel width(m)	Average Channel depth(m)
Site 1	70	11	0.9
Site 2	70	7	0.5
Site 3	70	4	0.2

3) Encroachment of farms and Infrastructural development.

Need for more agricultural land and establishment of commercial centers has led to encroachment of river basin. Infrastructural developments such as roads network, trading centers and settlements. They have impacted Thanantu River including its water quality, flood risk and consumption of water during construction periods. During construction, there's increased demand for water and so adding pressure on the river. They pollute and contaminate the water altering its acidity, salinity and aquatic species, through spills from pipes and vehicles, leaching of pollutants from construction and maintenance materials.

4) The decline in river discharge compared to the last years.

The river initially had more water and supported the locals. As at when the research was being conducted, there were a massive decline in its discharge and inadequate for all the locals in the Sub County. The river discharge has declined due to over-withdrawal of water and unregulated outflows by farmers, low rainfall and effects of climate change.

5.4 STRATEGIES AND EFFORTS IN PLACE FOR THANANTU RIVER RESTORATION AND ALTERNATIVES IN PLACE DUE TO ITS FLUCTUATIONS.

The third objective of the study was to determine strategies and efforts in place in Thanantu River restoration and alternatives in place due to its fluctuations. Therefore, the research focused on both prior and current restoration activities, community involvement, how the community is coping with water fluctuations, efforts put in place due to fluctuation and alternative water sources. The data was collected from household questionnaires and interviews with relevant authorities.

5.4.1 Assessment of prior and current restoration activities

According to the household survey carried out, 19% were not aware of any restoration measures, 65% were not involved in any restoration activity and only 16% were actively involved. The main restoration measures they were involved in are planting trees and barrier retrofitting (removal of soil sacks placed in the river to obstruct water). This shows that a large number of the households that were aware of Thanantu River restoration were not involved in the restoration activities. This has contributed to the failure of any restoration mechanisms put in place.



Plate 5: Prior restoration mechanism

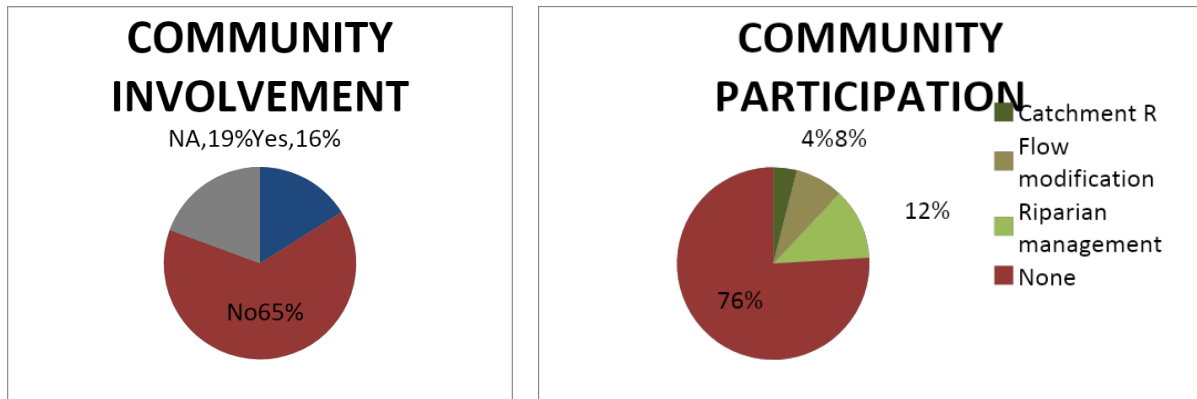


Figure 11 : Community involvement in restoration activities and mechanisms

From those who were aware of the restoration activity; 76% weren't involved in any, 12% were involved in riparian management, 8% were involved in flow modification and 4% were involved in catchment restoration.

It was noted that participation was not enough whereby they gave the following suggestions for its increment and improvement:

- ✓ Public awareness creation on restoration activities and their importance through public campaigns and public forums.
- ✓ Encourage formation of community groups. Formulation of community-based groups (CBOs) to empower and take responsibility for any decision made towards the management of the river.
- ✓ Community mobilization.
- ✓ Educate the community on impacts of overutilization of River water.
- ✓ Increase incentives such as labour wages so as to attract more people to take part in the exercise.

Most of the population were not aware of any strategies/mechanisms, policies, institutions, Associations or groups (both governmental and community organizations) responsible for protection, conservation, management and restoration of Thanantu River. The following strategies were identified; Riparian Management, Barrier Retrofitting, Awareness creation, Legislations, and regulations. The identified institutions were; Ministry of Irrigation and Agriculture whom their roles was to ensure there's water flow downstream through barrier retrofitting, so as to sustain irrigation projects in place such as Rwatha- Karethani Irrigation project.

Some individuals were also involved in the conservation of Thanantu River at a personal level, whereby they planted trees as a buffer between their farms and the river bank while others preserved the river bank by farming away.

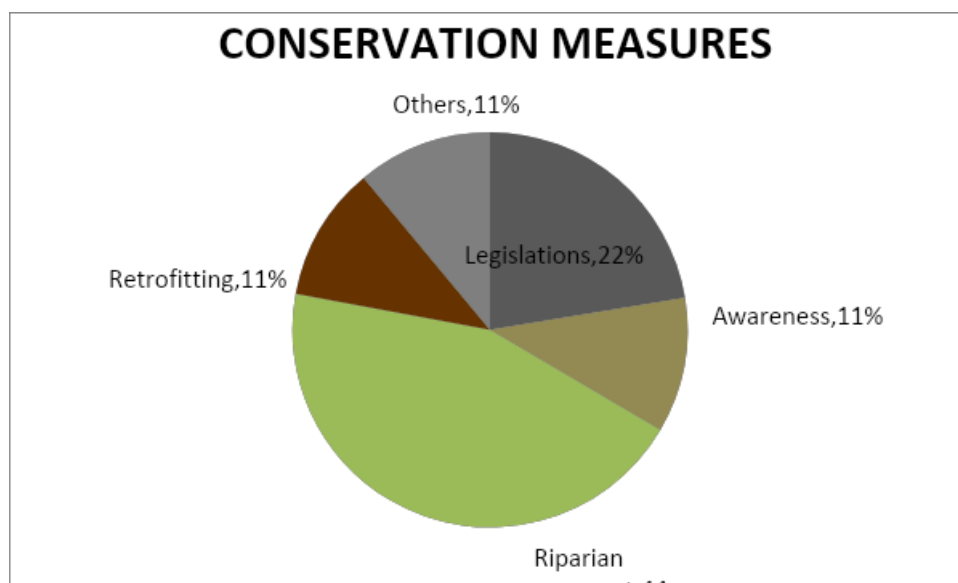


Figure 12: Thanantu River conservation measures

5.4.2 Alternative water sources

Water sources include Dams, Rivers, Lakes, Wells, Boreholes and Rainfall Water sources in Tharaka North Sub County range from Rivers, Boreholes (Hand pump and Public Tap) and Rainfall. These are used for both domestic and farm purposes. Thanantu River is the main source of water together with other permanent rivers such as Thangatha and Ura. From the 38 respondents; 61% depend on the river as their domestic water source and 71% use the same river for farm purposes. 51% use rainwater as their domestic source while 16% use it for farming and 45% use borehole (includes hand pump and public tap) water for domestic purpose while 36% use it for farming.

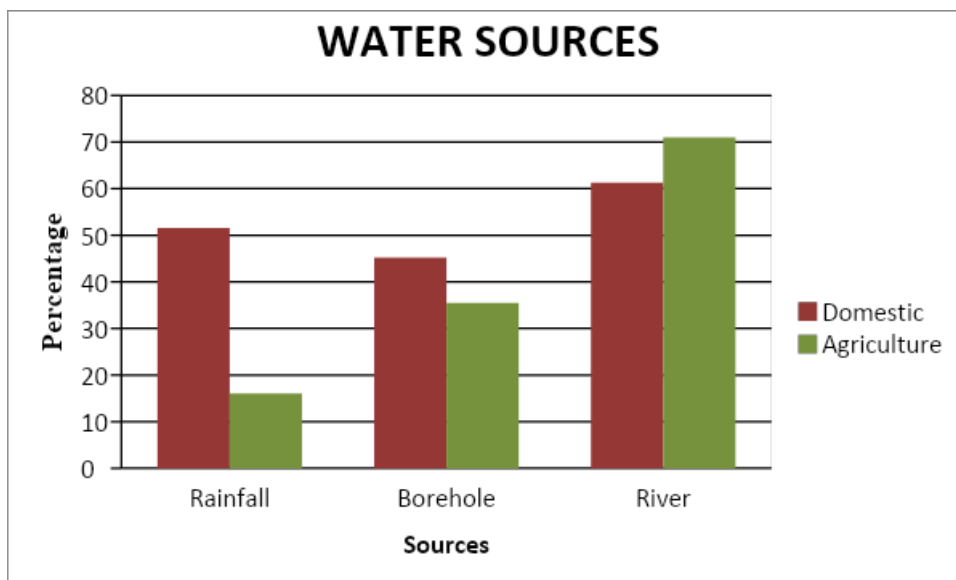


Figure 13: Domestic and agriculture water sources in Tharaka North Sub County

With the rate of water fluctuations from Thanantu River, the locals depend on other water sources. These alternatives include; Boreholes- Public taps and Hand pumps, Rainwater harvesting, and other rivers such as Kathita while some dig up the River bend when it dries. There are water projects such Kathita locally known as *Ruuji rwa baatiri* which is mostly dependent by Gatunga ward residence while those from Mukothima ward depend on Mukothima Water locally known as *Ruuji rwa Karau*. Tharaka North residents highly depend on these two projects which are in charge of piping water into dwellings and public taps. Most of the hand pumps in the area have dried up but some are being revived by a non-governmental organization through the installation of solar which is to pump water instead of the hand pump. They are managed by selected individuals.

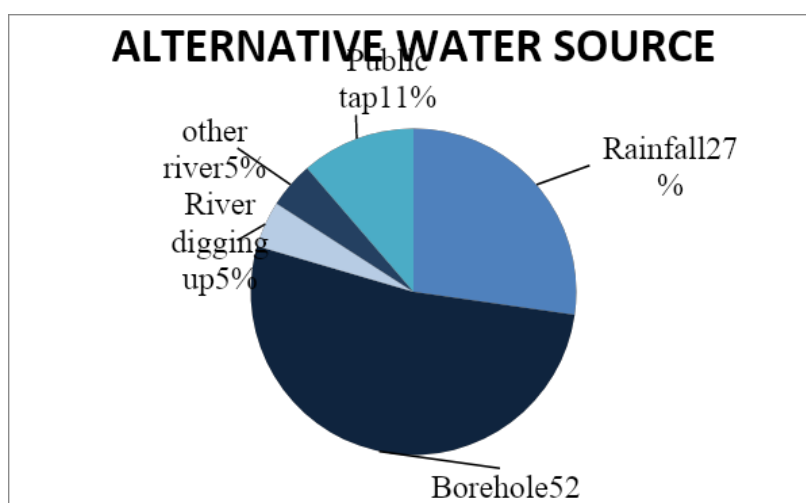


Figure 14: Alternative water sources for Thanantu River in Tharaka North Sub County

5.5 IMPORTANCE, CHALLENGES AND OPPORTUNITIES OF THANANTU RIVER RESTORATION.

The household survey carried out in Tharaka North Sub County had 38 respondents and came up with the following importance of Thanantu River restoration:

- Increase water storage. The river is the main source for water to the community. Its restoration will increase water storage and provision of adequate clean water for consumption.
- Increase the production of food. The area depends on agriculture which is their main activity. Through restoration of Thanantu River, there will be an increased number in irrigation projects leading to increased food production; therefore, curbing hunger and drought experienced most of the time in the area.
- Promote social cohesion by connecting of communities. The river connects two communities (Tigania and Tharaka) who are in conflict. The drying of the river has heightened conflict between the two. Its restoration will connect the communities as they will mix during the exercise and solve their difference as both will have access to water.
- Promote economic growth and agricultural sector. Residents of Tharaka North Sub County depend on agriculture for income generation. Thanantu River restoration will bring about growth in the agricultural sector resulting in economic growth.
- Provision of social, economic and natural services. The river plays a vital role in the provision of social, economic and natural services, thus its restoration will provide a quality environment.
- Provide shade and cool temperatures

While challenges facing the restoration activities of Thanantu River include:

- Resistance by both obstructers and ignorance by community members. The locals are unwilling to cooperate.
- Lack of knowledge and awareness of the importance of restoration, what it entails and impacts of water overutilization.
- Financial restrains. They are not enough funds to foresee the restoration process from the planning stage, design, construction to monitoring stage.
- Weak Institutions. The Sub County and County at large, lack relevant authorities and institutions in-charge of river/ wetland protection, management and conservation. This has made restoration exercise difficult as there is no personnel to follow up and set rules and regulations in terms of river management.
- Poor mode of communication between the locals and other stakeholders. Communication play role in restoration. The message of restoration is not communicated completely thus affecting willingness.

Nevertheless, there are opportunities that can make the restoration more successful. The household survey and institution interviews indicated the following opportunities:

- Awareness creation
- Formation of groups and associations
- Formulation of legislation, rules and regulations on those next to the river.
- Investigations and analysis of the initial causes of fluctuations so as to come up with a long-term strategy.
- Enforcement of rules on those farming using irrigation.
- Implementation of obstruction fines.
- Establishment of relevant authorities and institutions in the Sub County as those that are responsible are in the neighboring county (Meru County).
- Solving of conflict between Tharaka North and Tigania who live on the upstream side and abstract water. This will promote the cooperation of both communities in restoration on Thanantu River.
- Provision of seedlings to be planted as buffer zones.
- Temporal fences around the planted trees until they are mature.
- Educate on the importance of restoration.

5.6 PLANNING MATRIX

Table 8: Planning Matrix

Project Objective	Issues	Strategy	Recommended Measures	Activities	Time	Actors	Input	Output/ Expected outcomes
Strategies and efforts for Thanantu River restoration	Unregulated outflows.	Awareness and programmes on river restoration.	Implementation of River protective and conservative policies.	Forums	Continous	Tharaka-Nithi County Government Meru County Government Community Members WRUAs WRA NGOs National Government NEMA	Finance Professional Expertise Labour Standards Tree Seedlings	Scheme for management of the project to be of benefits to all. Restoration to the permanent state. Community sensitization. Unity Fewer deposition of sediments by runoff Less evaporation Restoration of riparian condition. Less pollution rates from the surface water. Cool temperatures. Normal and increase in river discharge.
	Encroachment of the river basin.	Provision of Incentives due to active participation in restoration process.	Mapping of riparian areas and the establishment of buffer zones.	Education and training on alternative farming techniques, water reusing and recycling, water harvesting and storage methods, coping mechanisms				
	Loss of flora and fauna	Monitoring and Management.	Awarding of legal title deeds to those that have land next to the river.	Free water connection.				
	Water stress	Re-afforestation.	Planting of indigenous trees with high survival rates.	Tree Planting and seedlings provision.				
	Water Pollution.	Capacity Building and education – environmental conservation, sustainable land management e.g tillage near the riparian, use of water resources.	Introduction of green agricultural practices and practice land uses that are river friendly.	Stakeholder involvement in law and policy formulation. Conducting water quality, quantity and abstraction surveys.				
	Poor communication between stakeholders	Establishment of Buffer Zones. Protection and conservation of the river.	Establishment of one common water intake for abstracters.	Provision and educating on supplementary irrigation activities.				
	Resistance	Law enforcement on the illegal and legal points.	Enforcement of laws towards logging of trees within the river ecosystem and basin.					
		Regulation of water usage.	Use of farmer-farmer training and knowledge.					
		Active WRUAs.	Re-introduction of Agriculture extension Officers.					
		Identification of drivers and pressure of river discharge fluctuation.	Use of farmer-farmer training and knowledge.					
	Licensing- water abstractions.	Introduction and training of sustainable farming practices which considers ecological factors such as managed grazing and better water management						
	Maintain the 30% river flow at all time and most especially during dry seasons for downstream users.							

Supplements and alternatives for Thanantu River discharge fluctuation.	Water stress.	Construction of Earth Dams.	Educating the locals on rooftop rainwater harvesting mechanisms.	Training and educating on sustainable agriculture methods and construction of environmental friendly dams and pans.	Continuous	TharakaNithi County Government	Finance	Increase in river discharge.
	Water Use Conflict.	Construction of Water Pans.	Drilling of boreholes to reduce dependency on Thanantu as the main water source.	Construction		Community members	Profession expertise	Increase in food production.
	Poor farming practices.	Drilling of Boreholes.	Training and educating on water recycling and reuse methods.	Monitoring, Evaluation and feedback.		NGOs	Land	Economic growth.
		Rain rooftop water collection.	Establishment, introduction, training of sustainable methods of tapping water from water sources.	Pegging.		Meru County Government	Labour	Infrastructure
		Sustainable agriculture through sustainable farming techniques. Monitoring and management team. Water recycling and reusing.	Protection and conservation of floodplains.					Increase in river discharge. Irrigation Projects.
		Water retention.				National Government		Increase in flora and fauna.
						WRA		Conservation, protection, preservation and increase in biodiversity.
						WRUA		

VI. Summary of Findings, Conclusion and Recommendation

This chapter recapitulates the study and bestows recommendations as well as giving strategies on how the recommendations will be achieved.

6.1 SUMMARY AND CONCLUSION OF THE FINDINGS

The entire aim of the research is to assess effects of land use changes on Thanantu River and give mannerism in which a successful restoration and rehabilitation can be achieved. The selfstanding objectives were: to establish land uses up to last 15 years in Tharaka North Sub County, to establish the effects of land use changes on Thanantu River, to determine strategies and efforts in place for restoration of Thanantu river and alternatives in place due to its fluctuation and lastly, to come up with mechanisms for successful restoring of Thanantu River.

Using systematic sampling, data was collected from 38 households along Thanantu River in Tharaka North Sub County and purposive sampling for institutions. The key findings of the study were: The land uses identified were; Agriculture which is the main land use, Forest, Institutional, Industrial, Commercial and Transportation land uses. There has been a massive change in land uses over the last 15 years in Tharaka North Sub County, with the most change being the conversion of forest to agriculture. The agriculture is rainwater dependent for those living far from the river while irrigation fed by hose near Thanantu River.

Land uses have a correlation with Thanantu River and they are highly dependent. This is demonstrated by both positive and negative correlation between farm acreage, residence duration, activity duration, farming duration and distances between the river, farm and home variables; consequential changes in Thanantu River ecosystem and basin are noticeable. Land uses have negatively impacted Thanantu River. The water has depleted causing the river's fluctuations. The main effects land uses have on Thanantu River are water pollution affecting its quality and quantity, reduction in water level, loss of flora and fauna and river degradation.

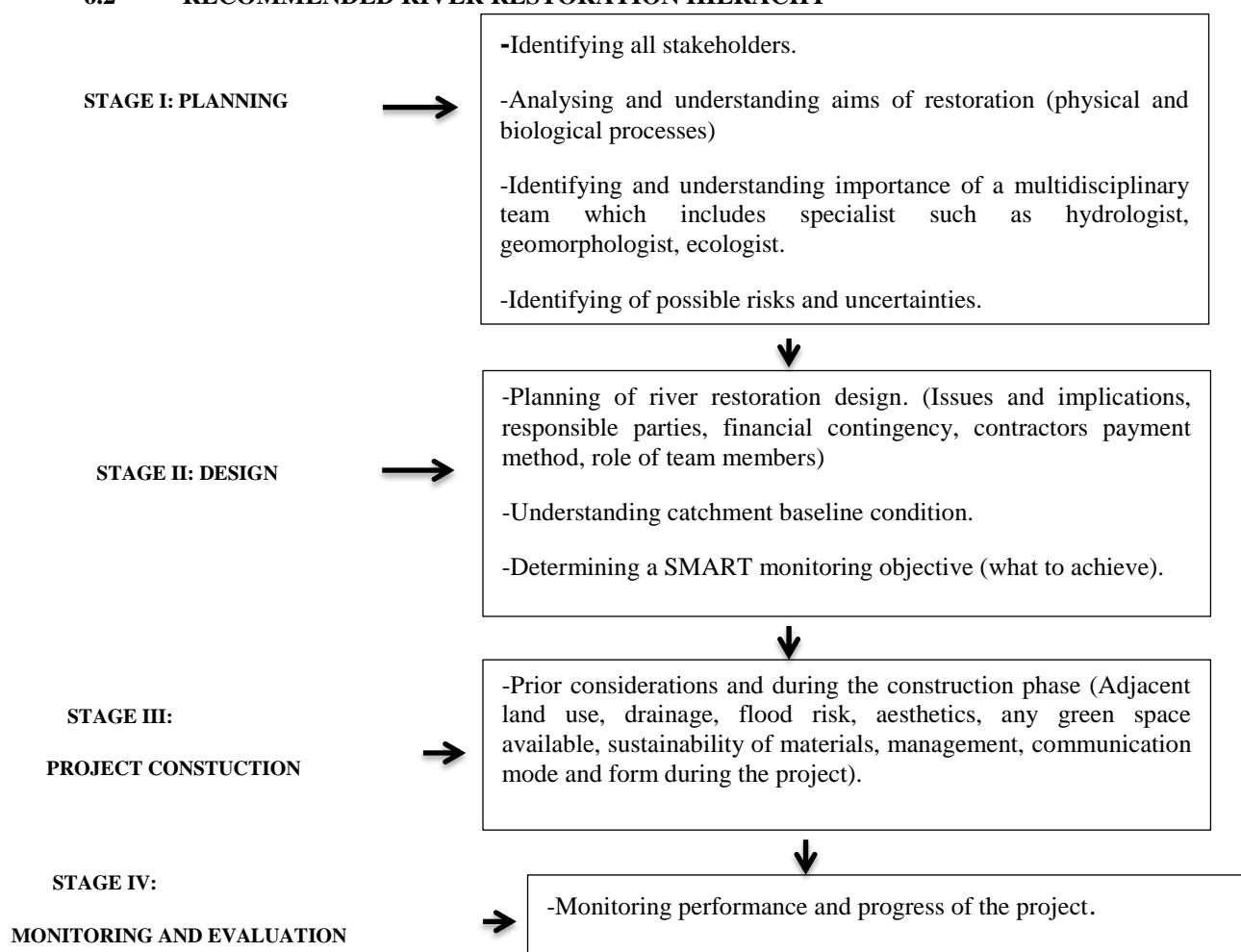
There are few operational alternative water sources, prior restoration efforts have failed and there are numeral challenges and opportunities facing restoration of the River. there's high dependency/ relation between land uses and the river and the community is willing to work hand in hand with both governmental and non-governmental institutions in pursuit of Thanantu River regeneration. They want to be involved in activities such as tree planting, formulation of regulations and laws and barrier retrofitting. Proper mechanisms to curb the challenges facing Thanantu River restoration should be put in place

Mechanisms that should be put in place in its restoration, rehabilitation and to eradicate the drying up include: Training and educating on sustainable agriculture methods and construction of environmental friendly dams and pans, Implementation of River protection and conservation policies, Mapping of riparian areas and

establishment of buffer zones, Planting of indigenous trees with high survival rates, Establishment of one common abstraction water point intake, Introduction and training of sustainable farming practices which considers ecological factors such as managed grazing and better water management , Educating the locals on rooftop rainwater harvesting mechanisms, Drilling of boreholes to reduce dependency on Thanantu as the main water source and Establishment , introduction, training of sustainable methods of tapping water from water sources. With these measures, the river will be rehabilitated and restored to its condition as a permanent river.

Thanantu River is greatly depleting and degrading at a high rate and therefore requires immediate and long-term strategies to restore a vital water source. The river is of high valence to the local people whom directly depend on it and also of great importance to Kenya as a whole, as it's a tributary of River Tana which is a major Kenya's water source. The strategies and efforts put in place in the restoration of the river aren't sufficient, thus more and better plans are needed for the attainment of its restoration.

6.2 RECOMMENDED RIVER RESTORATION HIERACHY



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