CHARLES KISIMA KIMANI

A Thesis submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Management of South Eastern Kenya University

2024

DECLARATION

I understand that plagiarism is an offence and I therefore declare that this thesis report is my original work and has not been presented to any other institution for any award.

Signature: ………………………………………. Date: ……………………

Charles Kisima Kimani

1501/WTE/20248/2012

This thesis report has been submitted for examination purposes with our approval as University Supervisors.

Signature: ………………………………………. Date: ……………………

DR. Patrick Kisangau

Department of Life Sciences

School of Science and Computing

South Eastern Kenya University

Signature: ………………………………………. Date: ……………………

DR. Margaret Owuor

Department of Hydrology and Aquatic Sciences

School of Agriculture, Environment, Water and Natural Resources Management

South Eastern Kenya University

ACKNOWLEDGEMENT

I would like to express my gratitude to my supervisors, Drs. Patrick Kisangau and Margaret Owuor, for their unwavering support throughout the drafting of my thesis and the course of my studies.

I also want to thank the faculty at Wote campus for their moral support during my studies and SEKU's administration for making it possible for me to study there logistically.

I want to express my gratitude to GATSBY AFRICA, my employer, for giving me the chance and resources to pursue my master's degree at South Eastern Kenya University. I am indebted to the Makueni County government staff Department of Lands, Urban Development, Environment and Climate Change, Department of Water and Sanitation, Self-help group leaders, Water Resource Users Group Leaders and all respondents for their cooperation during data collection.

I wish to express my deepest gratitude to God for life and for enabling me to carry out this work, not forgetting my brothers and sisters in Christ for their encouragement which gave me motivation to complete this study.

Finally, I must express very profound gratitude to my parents and my wife for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

DEDICATION

I dedicate this work to my dear family: My wife Mercy Mueni, my son Israel Amani and my daughter Joy Imani for their great support and compassion as I was completing my thesis paper.

TABLE OF CONTENTS

CHAPTER THREE

CHAPTER FOUR

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ACRONYMS

CBO	**:**	Community-Based Organization
CSOs	**:**	Civil Society Organisations
EPA	**:**	Environmental Protection Agency
FGD	**:**	Focus Group Discussion
GIS	**:**	Geographical Information System
GPS	**:**	Global Positioning System
KEFRI	**:**	Kenya Forestry Research Institute
LVB	**:**	Lake Victoria Basin
MOW	**:**	Ministry of Water
NGOs	**:**	Non-Governmental Organisations.
PAFRI	**:**	Preserve Africa Initiative
PVA	**:**	Population Viability Analysis
SES	**:**	Socio-Ecological Systems
SPSS	**:**	Statistical Package for Social Sciences
WRMA	**:**	Water Resource Management Authority.
WRUA	**:**	Water Resource Users Association

ABSTRACT

The degradation of riparian ecosystems poses a threat to the livelihoods of communities that depend on these socio-ecological systems (SES) for their well-being. Changes in riparian ecosystems have been evidenced by increasing water shortages and the loss of important and previously common riparian plant species. The riparian ecosystem in Kenya's Eastern Semi-Arid Region is one of the affected zones and information is required to better manage these resources. This case study focussed on the Kaiti River in Makueni County and analysed the socio-economic factors leading to degradation, its effects and physical degradation indicators to inform management strategies to improve the conservation of similar riparian ecosystems in the southeastern region of Kenya. Data was collected using questionnaires, key informant interviews, focus group discussions, transects for key indicator species mapping and photographs. To analyse the data, SPSS version 26.0 interfaced with Chi-square tests, regression and correlation analysis were used to draw relationships between socio-economic factors, effects, and degradation in the watershed. Crop farming was found to be a leading cause of degradation (r square=0.849, $F(1, 99)=9.4495$, $p \leq 0.05$) showing that farming accounts for 84.9% of the variations in the degradation of the Kaiti River riparian ecosystem. A calculated beta value implied that a unit raise in crop farming will lead to a rise in degradation of the Kaiti River riparian ecosystem by 0.782 ($p \leq 0.05$). The results of the study also revealed that livestock farming (r square=0.615, $\beta=0.211$, $p \leq 0.05$), Lack of riparian conservation awareness (r square=0.573, $\beta=-0.757$, $p \leq 0.05$) and Commercial sand harvesting (r square=0.659, $\beta=0.205$, $p \leq 0.05$) significantly contribute to Kaiti River riparian ecosystem degradation. Other causes significantly contributing to degradation (r square=0.520, $\beta=0.212$, $p \leq 0.05$,) were poor natural resource governance, poverty, poor infrastructure, climate change and land use changes. The main effects due to degradation were effects on crop production ($p \leq 0.05$) with the most significant effect being reduced availability of water for irrigation($p \leq 0.05$). More effects were on livestock keeping ($p \leq 0.05$) water availability for domestic use ($p \leq 0.05$) and more significantly on the ecosystem's biodiversity ($p \leq 0.05$). The study found vegetation change, disappearance of bird species, and reduced water flow, to be reliable general indicators of riparian degradation ($p \leq 0.05$). Ten degradation plant indicator species including *Ipomoea kituiensis* and five high water table indicator species including *Phragmites mauritianus* were identified. The study concludes that awareness creation and control of human activity in the Kaiti River riparian zone would significantly reduce degradation. A multi-stakeholder approach whereby the community takes centre stage in monitoring and implementing riparian conservation measures is recommended.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Riparian ecosystems are referred to as vegetation, habitats, or ecosystems that are connected to bodies of water. They include a wide range of habitat types, such as marshes, riverbanks, and floodplains. These ecosystem types are distinguished primarily by serving as ecotones, or transitional zones, between nearby terrestrial and aquatic realms. In comparison to nearby upland areas, riparian ecosystems typically represent wetter, colder, and more varied habitats, which tend to support biologically unique, productive, and diversified communities. (Suring, 2020).

Both humans and other creatures prefer riparian environments over other types of forested places due to the uniqueness of the ecosystems including high soil fertility, water and biomass (Schmitt, Kisangau, & Matheka, 2019). According to Singh R., Tiwari, & Singh G., (2021), although they offer essential services and goods like food, water, and shelter, they are the parts of our environment that are most frequently mistreated, misunderstood, and abused. They provide early warning signs of eroding and polluted conditions that endanger forest streams, rivers, lakes, and ocean fronts. They also suggest that when there is a change in water quality, the basic ecology is severely disrupted.

Degradation of land and watersheds is a global issue that has a negative impact on the functionality and integrity of watersheds. These ecosystems are vital to local communities and national economies, supplying them with the commodities and services they need to survive (Kieti et al. 2016). Among the ecosystem functions affected include fodder for livestock and water for domestic, agricultural and wildlife use. Land-use changes are putting the ecological stability of river systems in peril across the world. A serious and persistent threat to biodiversity and the preservation of lotic ecosystems is posed by the extensive and rapidly expanding phenomenon that involves urbanization, agriculture, pasture conversion, deforestation, and the replacement of native species with exotic ones that have commercial value. (Miserendino et al., 2011).

Kenya is categorised as a nation with water scarcity and is facing water resources management issues, which arise due to ineffective management of the soil surface and water catchments, failing water management infrastructure, and insufficient control and enforcement of water extraction from streams and rivers (Matunda, 2015). The Lower Tana River woodlands in northern Kenya, which are fragments of floodplain forests sustained by the river's groundwater and flooding, are an excellent example. They are sensitive to changed hydrological conditions and clearing for cultivation, yet they offer various ecosystem services to nearby populations and habitats for threatened monkeys (Julia, 2008). Compared to other transboundary lakes in the area, the Lake Victoria Basin (LVB) faces significantly more complicated social, economic, political, and technical obstacles. The ecosystem of the Lake has been significantly impacted by the environmental degradation of LVB during the past three decades because of the excessive use of natural resources. These include significant algal blooms, waterborne illnesses, an invasion of water hyacinths, and oxygen reduction. (Odada et al., 2004).

Degradation is happening in almost all riparian ecosystems in the country, with Eastern Semi-Arid and Arid lands being part of it (Kieti et al. 2016). While riparian ecosystems are well studied globally, little data exists to provide evidence-based insights into the underlying causes of riparian degradation and quantify the effects encountered in semi-arid regions of Kenya. Studies on riparian degradation indicators are also very limited. Only recently, Schmitt, Kisangau, & Matheka, (2019) documented a related study on tree diversity in a human-modified riparian forest landscape in semi-arid Kenya. According to Miserendino et al., 2011, understanding how gradually or locally human activities could scale up to damage local biotas is necessary for managing present threats to global biodiversity. Therefore, the purpose of this study was to ascertain the causes and effects of riparian degradation as well as identify suitable degradation plant indicators for semi-arid riparian ecosystems with Kaiti River being a case study.

Below (Plate 1.1) is a photograph showing the current state of the Kaiti River with traces of degraded Phragmites, eroded sand and exposed rocks.

Plate 1.1: A section of the degraded Kaiti River showing traces of degraded phragmites, eroded sand and exposed rocks.

1.2 Statement of research problem

In Makueni County, the Kaiti River and its tributaries served as grazing zones during the dry seasons and were defined by thick vegetation and tall trees. These resources have been degraded and reduced in cover threatening the survival of livestock in the dry seasons. In a study by Malombe et. al., 2012, on the biodiversity of the Kaiti River watershed, they state that in the Upper Kaiti River areas of Kivani, the river used to have flowing water throughout the year about 20 years ago, but the water was now found in a few sections and only during and one month after the rains. Riverine vegetation species like Phragmites which used to appear in thickets and formed suitable ecological niches for wildlife like birds and acted as mitigation measures against drought and famines both for humans and wildlife have been greatly reduced (MEWNR, 2013).

Due to the rapid degradation and limited information from research on riparian degradation, its effects, and indicators especially in Kenya and the Kaiti River riparian zone, little is being done to execute the interventions and that which is being done in the watershed was not based on scientific data (Julius, 2013). This study sought to gather Empirical information on the degradation causes, effects, and possible plant indicators, that would help in the development of appropriate conservation interventions.

1.3 Objectives

1.3.1 General objective

The main objective of the study was to assess the causes and effects of riparian ecosystem degradation on the Kaiti River, Makueni County, Kenya.

1.3.2 Specific objectives

i. To determine the socio-economic factors contributing to riparian ecosystem degradation in the Kaiti River.
ii. To establish the effects of riparian ecosystem degradation on the Kaiti River riparian ecosystem.
iii. To identify plant indicator species of degradation in the Kaiti River riparian Ecosystem for monitoring and management.

1.4 Research Questions

i. What are the specific socio-economic factors that have contributed to riparian ecosystem degradation in the Kaiti River riparian ecosystem?
ii. What are the effects of riparian ecosystem degradation in the Kaiti River riparian zone, both on the ecosystem itself and the surrounding community?
iii. What are the key plant indicator species in the Kaiti River riparian zone, that can be effectively used for monitoring and management purposes to mitigate further degradation and promote restoration?

1.5 Significance of the Study

Information on socio-economic causes, effects and reliable indicators of riparian degradation is key to sustainable reclamation and maintenance of the riparian ecosystems in Kenya. Knowledge about the causes is an eye opener to enable proper planning to mitigate the causal factors and consequently reverse degradation and minimise associated adverse social-economic and environmental effects. This research will establish the effects of degradation on the river Kaiti River riparian zone which will give direction on interventions by relevant authorities. The identification and documentation of key indicators such as plants helps in riparian ecosystem management and monitoring. Recommendations from the findings of this study will form a basis for informed policy-making and appropriate interventions for sound management of the riparian ecosystems by the County Government and relevant national government agencies including NEMA, WRMA, and Ministry of Environment, Water and Natural Resources. The information would also be useful to development partners who would be willing to mitigate riparian ecosystem degradation based on credible information. These include NGOs and other CSOs.

This study setup and the selected study area serves as a model to better understand related riparian ecosystems of the lower Eastern Kenya.

1.6 Scope of the Study

The study only covered the Kaiti River watershed which is approximately 660 km2. Household data was collected within this scope and focus group discussions were held with groups found within the watershed. Sampling transects were established along the course of the Kaiti River running from its source in Kee to the lowest point where it meets Thwake River. Only key informants with a leadership mandate over the watershed were consulted. The main data sets collected included riparian degradation causes, effects and plant indicators.

1.7 Assumptions

In this study, it was assumed that: -

i. Nature if undisturbed is self-regulating thus degradation is mainly a result of human-related socio-economic factors.
ii. The data collected from respondents and key informants are accurate and truthful.
iii. The sample size is adequate to reflect the subject matter under research.

1.8 Conceptual Framework

This research work was framed on the conception that riparian ecosystem degradation is a dependent variable that relies on how the government and other moderators handle the causal factors (independent variables) as demonstrated in Figure 1.1. The study also assumes that the establishment of suitable interventions to tackle riparian degradation would require sufficient information on the causes and effects of riparian degradation and would need knowledge of degradation indicators for proper measurement of degradation status and intervention progress.

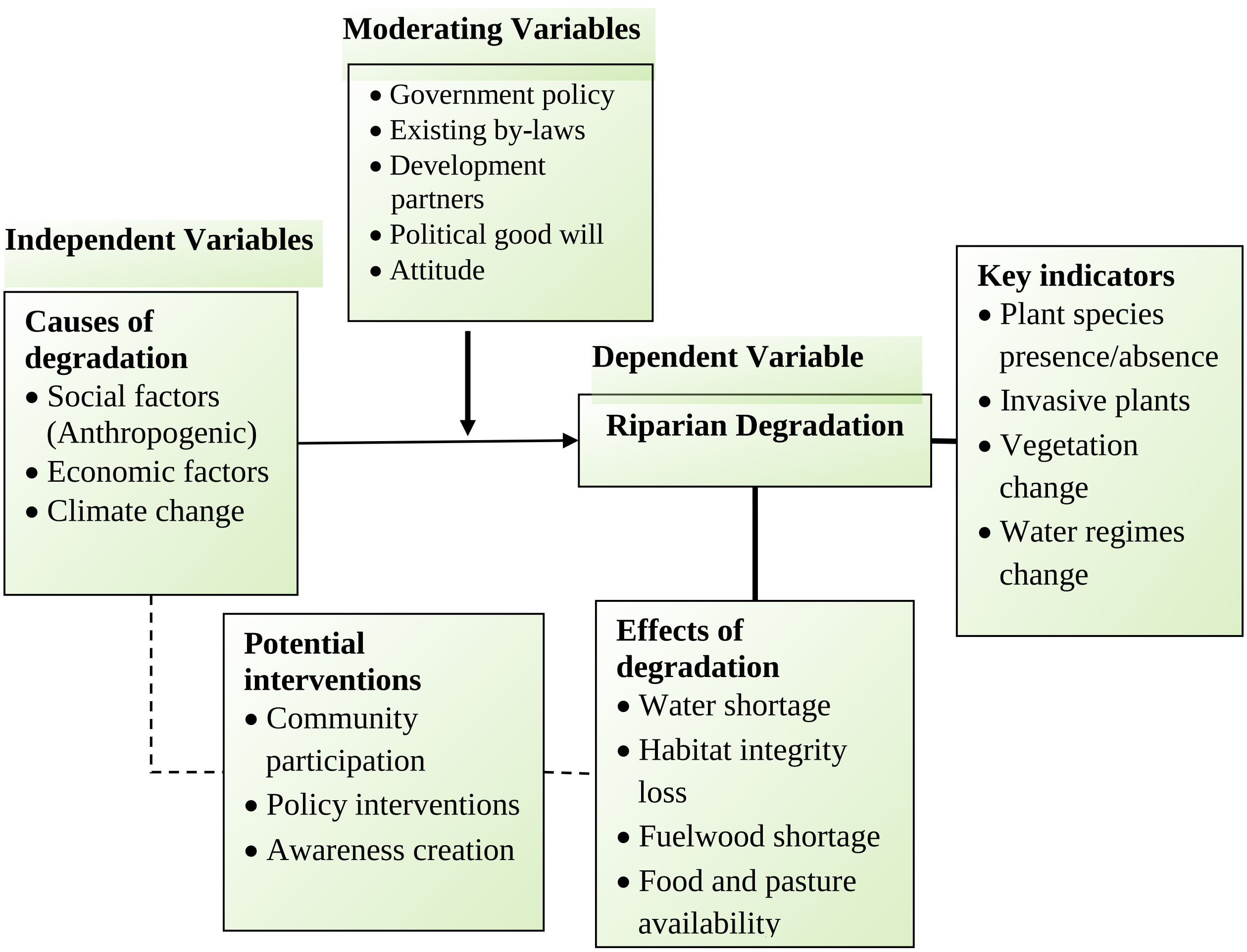


Figure 1.1: Conceptual Framework

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter aims to reveal relevant studies in riparian ecosystems and the gaps which the study intends to fill. Degradation of riparian ecosystems is currently one of the greatest concerns and information on the actual factors contributing to their degradation and sustainable management practices/strategies is scanty, which this study aims to address.

2.2 Riparian Ecosystems Description

The Latin term "riparius," which means to be on or to belong to a river bank, is where the English word "riparian" gets its origin. The term "riparian zone" describes a larger area that extends from the riverbank to the floodplains; on occasion, it also includes hill slopes that could have an impact on the stream environment. The phrase can also be used to refer to lakeshores and wetlands according to Chen et. al., (2019), who say that riparian zones are the areas that bridge the gradient between aquatic and terrestrial ecosystems and serve as functional connectors between land and freshwater bodies. They are the three-dimensional ecotones of interaction that encompass both terrestrial and aquatic ecosystems, extending lateral into the terrestrial ecosystem, up near slopes that drain to the water, outward across the floodplain, and along the watercourse at a varying width (Suring, 2020).

According to Gashaw et al. (2015), riparian zones are thin strips of land found along rivers, lakes, potholes, springs, coulees, wooded draws, or anywhere water is abundant. Riparian areas are vegetated ecosystems along a water body through which energy, materials, and water travel. Riparian habitats stand out from their surroundings due to the availability of water and plant communities that are distinct from those in the drier uplands.

2.3 Importance of riparian ecosystems

The economic and recreational benefits of riparian ecosystems are extensive further to the provisioning of essential goods and services. They have frequent flood and drought cycles, more readily available soil water, and a higher water table year-round, all of which contribute to the development of tall and dense hydrophilic vegetation, which is a convergence of high biodiversity and elevated ecological services (Zaimes et al., 2019). Riparian regions are home to a wide variety of plant, insect, bird, and mammal species. The vegetation has many advantages, including acting as a habitat for both terrestrial and aquatic organisms, stabilizing stream banks, shading streams, improving water quality, reducing floods and stabilizing shorelines. The vegetation also facilitates groundwater exchange, adding organic matter, acting as buffer zones, filtering fine sediment from runoffs, absorbing excess nutrients from runoffs, and increasing runoff infiltration to groundwater (Gashaw et al., 2015).

According to Suring (2020), riparian vegetation can help regulate water quality and provide habitats for different types of aquatic and terrestrial organisms. It can also prevent riverbank erosion and promote landform stability. The role of riparian ecosystems in the assessment and vulnerability of human and natural systems to climate change is becoming increasingly critical because they also influence the systems' ability to adapt. There is a possibility that the evolution of these ecosystems over time has contributed to their resilience to climate change (Samantha, 2013).

In semi-arid regions of Africa, vegetation patches in riparian areas help to prevent runoff, and the trapped water subsequently promotes patch development, which gives the system feedback (Richardson et al., 2007). Riparian ecosystems contribute to the national economy both directly and indirectly by providing and sustaining cultural services. Unfortunately, the management of riparian areas has been hampered by various factors such as the encroachment of industrial and agricultural activities, pollution, and eutrophication. In addition, the lack of proper resources and the overlapping mandates of different agencies have also affected the development of these ecosystems (MEWNR, 2013).

Capon et. al., 2013, argue that in the twenty-first century, riparian habitats will probably be crucial in identifying how susceptible human and environmental systems are to climate change as well as affecting their ability to adapt. According to some writers, riparian habitats' high vulnerability to and sensitivity to climatic stimuli, along with their history of deterioration, make them especially vulnerable to the effects of climate change. Others have emphasized that because riparian ecosystems have evolved in an environment with high levels of climatic and environmental fluctuation, they are likely resilient to climate change. Rapid climate change is however likely to modify groupings of species and environmental traits, creating novel habitats. (Catford et. al., 2013).

2.4 Causes of Riparian ecosystem degradation

Riparian ecosystems are among the most changed, degraded, and vulnerable ecosystems on Earth largely due to their location in the landscape and being regions of intense human activity (Suring, 2020). Riparian habitats are severely degraded by human water use since they are situated adjacent to important waterways. Around the world, riparian regions have been diminished or removed by forestry, agriculture, urbanization, and other human land uses, with deforestation being a primary driver of riparian habitat deterioration (Boisjolie et. al., 2020).

A growing number of riparian lands have been developed and used in recent centuries for agriculture, habitation, and the growth of cities and towns. Critical catchment areas have been severely impacted, which has changed the water quality in aquatic ecosystems (Matano et al., 2015). Numerous additional rivers are restrained by man-made dikes or levees. The activities and processes of ecosystems in running rivers and related surroundings have changed because of hydrological modifications made to ensure water for agricultural, industrial, and domestic needs; for hydroelectricity; or to protect against floods (Nilsson et al, 2.000).

Dams are another major contributing factor to riparian degradation across the whole world. The normal river flow patterns are changed by dams, which also retain silt, altering historical channel dynamics, fluvial geomorphology, and vegetation disturbances downstream in addition to converting lotic systems into lentic systems. The majority of the time, these changes have a significant impact on the species, geographical and temporal distributions, and architecture of riparian vegetation. Dam construction is one of the primary causes of the large freshwater discharge reduction in the Mediterranean region's rivers. (Zaimes et al., 2019).

Land-use changes are putting the ecological stability of river systems in peril all across the world. A serious and persistent threat to biodiversity and the preservation of tropical ecosystems is posed by this extensive and rapidly expanding phenomenon that involves urbanization, agriculture, pasture conversion, deforestation, and the replacement of native species with exotic ones that have commercial value (Miserendino et al., 2011). Because of their high levels of vulnerability and sensitivity to climatic stimuli, as well as their long history of degradation, riparian ecosystems have been especially sensitive to climate change impacts (Samantha, 2013).

The growing lack of sustainable use of wetlands, particularly in developing nations, can be linked to a failure to recognize the historical significance of these wetlands, as well as a drive for modernization and a failure to appreciate their ecological role. Water management decisions including water diversion, impoundment, or withdrawal, like land-management operations, can affect hydrological processes, lessen flooding of riparian floodplains, and transform riparian ecosystems (Boisjolie et. al., 2020).

Recent land use studies in East Africa point to agriculture as the main cause of wetland degradation. Nzau et al. (2018) noted that ecosystem degradation is particularly prevalent in watersheds in the semi-arid region of southern Kenya, where previously pristine riparian forests have been converted to agriculture, fields and habitats, damaging ecosystem services.

The riparian vegetation in the low dryland in Eastern Kenya has been affected by anthropogenic activities to a significant extent. Rapid population growth, high poverty levels, land use changes, poor land use systems, and deforestation aggravate the situation in Kenya, particularly in Makueni County, leading to food crises and land/watershed deterioration. (Kieti et al. 2016).

2.5 Effects of riparian degradation

2.5.1 Upstream effects

To meet water, power production and transportation needs, people built over 300 monster dams (which have a tallness of over150 m, dam volume of over 15 million m3 or store capacity of over 25 km3) and an astounding number of littler dams, taking off over half (172 out of 292) of the worldwide expansive streams divided (Haipeng et al., 2019). Storing all of this water will have far-reaching environmental repercussions. These include habitat loss due to flooding and the creation of new riparian zones. The most common upstream effect of a dam is an increase in water volume, which floods upland and riparian habitats. Dams have expanded the amount of an existing lake in some circumstances, but in many cases, rushing waters have been transformed into reservoirs, resulting in permanent habitat loss.

This impact is particularly significant where water reservoirs are near mountains, in dry ranges, or within the distant north where river valleys are often the foremost profitable scene components. Since numerous species in these situations are limited to valley bottoms, large-scale impoundment of water is likely to quench whole populations. The beginning impact of immersion on plants is through the root framework. The waterlogged soil becomes anoxic, and this leads to oxygen push and inevitable disposal of the essential root framework (Chen et al., 2019). Sá-Oliveira et al. (2015) discovered clear negative consequences on fish population, biomass, species richness, alpha diversity, and species dominance upstream of the eastern Amazonian hydropower dam in their study. Differences in the content and structure of fish groups were substantially associated with the physical subdivision of the river channel and the upstream channel shift from lotic to lentic habitats. Notable alterations in the reservoir included an increase in the contribution of small-bodied fish and the absence of long-distance migrants upstream of the dam.

2.5.2 Downstream effects

In the headwater areas of many regulated rivers, there are storage reservoirs, and downstream from these areas, there is an intact channel with a regulated flow. In such rivers, the flow of just about the whole river can be impacted by a single reservoir. The riparian zone and its surroundings will be altered by such a transformation, which may also result in salinization and the invasion of exotic species (Nilsson et al, 2.000). Large dams frequently have downstream effects that diminish and occasionally shift the flood peak, which in turn reduces the frequency of overbank flooding. Additionally, after the development of big reservoirs, increased water demand and evaporation losses frequently result in lower downstream discharge. Groundwater recharge in the riparian zone is decreased by altered hydrology downstream of dams, which results in a declining groundwater table. The size of the active floodplain is now smaller due to these modifications. Additionally, dams alter geomorphological processes like sediment cycling. Large quantities of the material that was once carried further downstream may be trapped in reservoirs. For instance, a dam constructed across the Maujira River, an Indian tributary of the Godavari River, lost 60% of its capacity to store water due to sedimentation in 43 years (Dogra, 1986).

Increased erosion occurs downstream of a dam as a result of a reservoir's water release because the water tends to replenish its initial load of nutrients and debris. This erosion causes the riverbed to undergo less geomorphologic activity, which results in a simpler channel, less point-bar deposition, less meandering of the river, and slower development of deltas and coastline erosion. Another illustration is the building of dams on significant rivers that empty into the Black Sea, where the sea's coastline has shifted due to less silt being transported there (Mee, 1992). English et. al., (1997) reported that the Slave River delta of Great Slave Lake, Northwest Territories, Canada, was markedly decreased after impoundment of the Peace River at Hudson’s Hope, British Columbia.

Ding et al., (2013) conclude in their study that hydrochory, the movement of seeds and clonal pieces downstream, can be disrupted by dams and reservoirs, which can lead to the downstream spread of riparian weeds. Numerous Chinese rivers that have been restricted by dikes that prevent significant portions of their floodplains from flooding nonetheless experience considerable siltation, which is why some of these rivers are now under regulation. The siltation causes the riverbed to rise and the overbank floods to become more severe. (Nilsson et al, 2000).

2.5.3 Riparian Adjacent Communities

Riparian communities within Semi-Arid and subarctic regions, wherein floods are extraordinarily critical for watering, fertilizing, cleaning, and sowing the land, are usually most seriously altered through impoundment due to the fact water is so scarce. Low-altitude regions are generally more vulnerable to riparian ecosystem changes than higher-altitude regions due to the fact the terrain is flatter and small alterations can also influence extensive areas (Nilsson C. *et al*, 2000). In these conditions, floodplain riparian ecosystems, which offer a variety of habitats and ecosystem services, are frequently the predominant wetland features in otherwise arid landscapes. When compared to nearby highland ecosystems, floodplain riparian ecosystems sustain disproportionately diversified plant and animal communities, with many species only appearing in great abundance in riparian zones. (Macfarlane et. al., 2017).

Due to the effects of riparian degradation on cattle and wildlife, millions of people are at risk of losing their means of subsistence. However, it has been noted that Lake Naivasha's bird and fish populations have decreased in recent years. Due to the significant contributions that African lake ecosystems make to the livelihoods and food security of millions of Africans, the goods and services that these ecosystems provide are under significant stress. This stress is primarily brought on by rising population levels, adverse anthropogenic effects on lake catchments, and high levels of poverty that lead to unsustainable use. All of these things have detrimental effects on biodiversity and human livelihoods. (Kafumbata et al., 2014).

2.6 Riparian Evaluation Procedures and Degradation Indicators

2.6.1 Evaluation procedures

Gonzalez del Tanago, & Garcia de Jalon, (2011) Say that the study of riparian systems is of tremendous scientific interest because the riparian habitat incorporates many interactions between the aquatic and terrestrial elements of the landscape and sustains the surrounding fluvial ecosystem throughout its entire length. Keeping it up is therefore essential to preserving river biodiversity. Because of how their state influences numerous environmental services associated with rivers, they continue by saying that riparian systems also serve as a crucial part of river management.

According to Briggs (1995), "One of the most important lessons learned from the experiences of past riparian mitigation efforts is the importance of evaluating site conditions to identify the causes of degradation". He maintains that the development of mitigation methods that specifically target the causes of deterioration rather than just its symptoms depends on the identification of degradation causes. The information needed to better understand the possible efficacy of re-vegetation to ameliorate deteriorated riparian environments will come from evaluating site circumstances.

Examining merely a watershed's components separately (for example, a specific stream reach) would frequently fall short of giving the details required to properly comprehend why the riparian habitat has deteriorated and is ecologically deficient. Therefore, the effectiveness of mitigation initiatives can be assessed by looking at degraded riparian habitats from a watershed viewpoint. The relationship between biotic ecosystems and other nearby ecosystems shapes biotic ecosystems' structure and processes more than any other form of ecosystem. (Singh R., Tiwari, & Singh G., 2021). A watershed disruption in any part will create a lack of equilibrium which will be felt by numerous ecosystems throughout the watershed through cascading impacts. Riparian habitats are most affected by changes in the sediment and water runoff from nearby areas since they are located in the bottomlands of a watershed. Disturbances (such as logging, livestock grazing, urbanization, etc.) along the watershed, tributaries, and neighbouring uplands have an impact on riparian ecosystems (Richardson et. al, (2007).

Therefore, resource managers should avoid a partial approach to developing mitigation strategies based directly on the assessment of degraded riparian sites. Mitigation measures based on this narrow measure will likely be ineffective as the conditions that caused the damage in the first place will continue to affect the area. The assessment process should include many aspects of riparian ecosystem basins, taking into account the conditions of the surrounding highlands, upstream and downstream water sources and tributaries. Brito et. al.,2020, in their study of how forest loss had affected riparian ecosystems of streams in the Amazon basin, concluded that it is not enough to focus management and conservation actions on riparian zones, but that conservation strategies should be expanded to entire catchments as well.

2.6.2 Riparian degradation indicators

Many authors approve of vegetation composition as a crucial indicator of riparian degradation. According to Macfarlane et. al., 2017, on many floodplains, the encroachment of woody invasive species or upland shrubs, serves as a prominent indicator of riparian habitat degradation. Hydrologic alteration that reduces the magnitude, duration and frequency of floods, for example, often precedes the expansion of invasive species along floodplains. In turn, the increased *invasive species* abundance reduces the riparian native species' physiological performance, shifting community composition further toward woody, non-riparian vegetation.

Tererai et al., (2013) say that many invasive species alter the composition, shape and functioning of native riparian ecosystems and some bring about great declines in native species diversity. In intense cases, invasions may also transform the nature or form of complete landscapes by manifesting dominance, superior competitive capacity and the modification of ecosystem parameters. They conclude that species richness, variety and structure of native species reduced constantly alongside the invasion gradient within the riparian zones of the Western Cape, South Africa. Invasion by *Eucalyptus camaldulensis* was closely correlated with changes in local plant species composition; even though a few local species passed off in alien-invaded sites, they have been extra ample in uninvaded locations.

Brito et. al., 2020, demonstrates riparian degradation evaluation by assessing aquatic macroinvertebrate assemblage changes both at the riparian level and in the riparian catchment. Olokeogun & Kumar (2020), In their investigation on how urbanization affects the riparian ecosystem in the Indian Himalayan metropolis, they employ maps of anthropogenic activity, including newly constructed homes, roads, agricultural operations, and commercial (industrial) setups, as indicators of the vulnerability of riparian zones. To create vulnerability maps, they also employed indicators such as the riparian zone's slope, size, vegetation cover, and mappings of human disturbance.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

A description of the study area and the methodology are provided in this chapter. It also describes the primary variables examined, the procedures used for gathering and analysing data, and the tools used for doing the research.

3.2 Area of study

3.2.1 Location and Administrative Division

The study was conducted in Makueni County which is in the lower eastern region of Kenya. The County borders Machakos to the northwest, Kajiado to the west, Kitui to the East and Taita Taveta to the southern side as shown in figure 3.1.

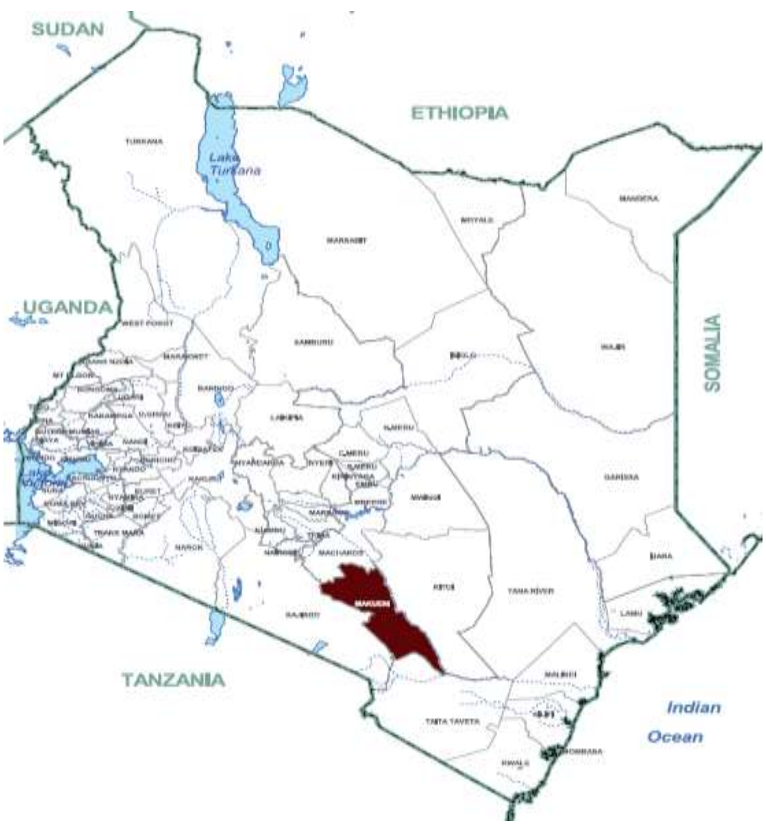


Figure 3.1: Map of Kenya showing location of Makueni County, Source: Kenya National Bureau of Statistics, 2009

The County hosts six major watersheds as shown in figure 3.2. Among the watersheds, the Kaiti River watershed though smallest in coverage is of key importance being the one that serves the county headquarters.

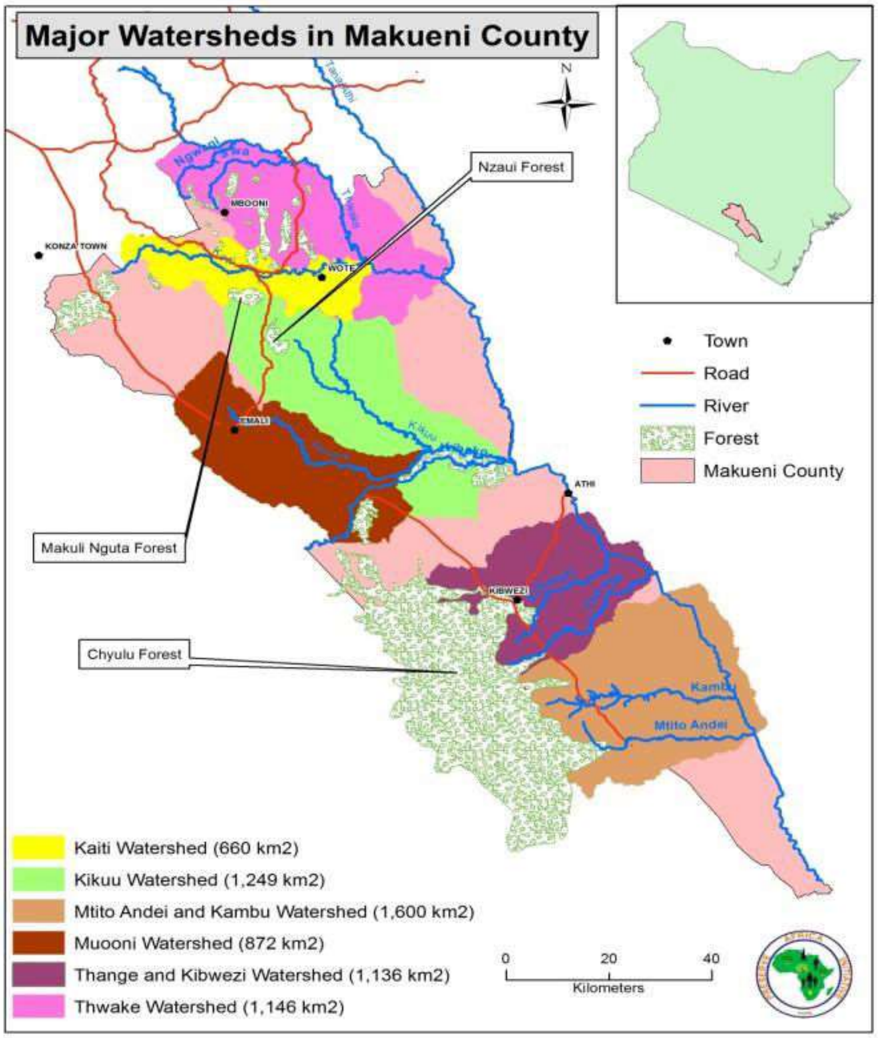


Figure 3.2: Makueni County watersheds; source PAFRI, Baseline survey maps (2012)

Data was collected along the Kaiti River watershed which covers an area of 660 km2 and is located between 10º 38´ South and 10º 51´ South and 37°14´ East and 37°41´ East. It comprises of Kilungu, Kee, Kalama, Kaiti and Wote divisions. The river flows through Makueni and Kaiti Sub-Counties but also extends to parts of Mbooni and Nzaui Sub-Counties (Kieti et al., 2016). The study focused on the Kaiti River watershed as shown in Figure 3.2.

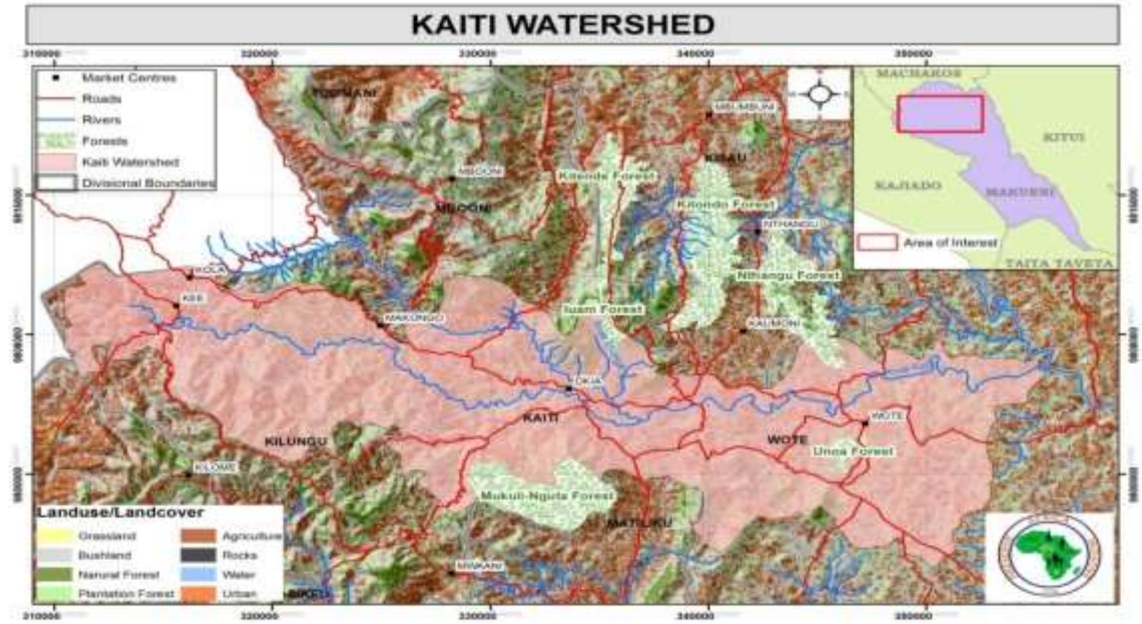


Figure 3.3: A map of Kaiti River watershed; source PAFRI, Baseline survey maps (2012)

3.2.2 Topography

At the southernmost point of Makueni County, Tsavo, the land climbs from just under 600 meters above sea level to around 800 meters. Low-lying grassland in Makueni County's southern region receives little rain but offers a great deal of potential for ranching. With its mountainous terrain and average rainfall, the County's northern region, which includes the majority of the Kaiti River watershed is more productive agriculturally. The Kaiti River watershed topography is characterized by mountainous terrain including Kilungu and Mbooni hills. Kaiti River and its numerous tributaries originating from the hills serve the watershed which influences surface water sources and groundwater recharge capacity (Kieti et al., 2016). Across the County, drainage generally runs from west to east. The County has several rivers and streams. Wote Town and residents of the Kaiti River Watershed receive water from the Kaiti River. (Kapp, 2011).

3.2.3 Climate and Rainfall

Makueni County is characterized by very variable precipitation. In general, wet seasons alternate with dry periods, and changes in the onset of the rainy season make it difficult to maintain an adequate food supply. The County has two rainy seasons, the highest in March/April (long rain) and November/December (short rain). The long drought period is from June to October, and the short period is from January to March. The Kaiti River watershed lies in the fertile upper parts of the county which experiences average rainfall of 800 mm-1200 mm. Other regions receive less than 500 mm of precipitation per year. The average temperatures range from 20.2ºC to 24.6ºC, but regular dry periods have recorded temperatures of up to 32ºC (Maluki et. al, 2016). High temperatures in the low altitude areas cause high evaporation (Karp, 2011).

3.2.4 Vegetation types and livelihoods

The native vegetation in the semi-arid region of Makueni County varies from grass to forest. Over the years, vegetation has changed due to fire and climate change factors. Previous studies show that there has not been complete deforestation to clear land but farmers remove bush leaving the precious trees behind (Gichuki, 2000).

There are three main livelihood zones in Makueni County: marginal mixed farming, mixed farming (coffee/dairy/irrigation), and mixed farming (food crops/cotton/livestock). The main crop grown is maize, which is the stable food in the district. Other crops grown in order of importance are cowpeas, beans, pigeon peas and green grams (Kapp, 2011). The study area is characterized by a high population and density of 120,116 and 248 persons per square Kilometer respectively as compared to the average of 110 persons per square kilometer for the county (GOK, 2013).

3.3 Research design

The study made use of a cross-sectional survey design that is both analytical and descriptive. Saris & Gallhofer, 2014, describe research survey as data collection from human participants through standardized questionnaires, where the focus is on the collective rather than the individual. Jansen, (2010), also describes a survey to gather information from a sample to establish a quantitative description of the larger group to which the sample belongs.

To determine degradation causes, effects and potential indicators, the survey collected primary and secondary data. For primary data, questionnaires were administered to respondents living along the Kaiti River riparian ecosystem. The respondents consisted of households, community groups, local institutions, and key informants in the respective areas of investigation. GPS point collection and photo capture were also employed. Transect sampling was employed in the identification of key indicator plant species.

Kaiti River was chosen as an ideal case to represent the rest of the riparian ecosystems in the Eastern Semi-arid region of Kenya.

3.4 Sampling procedure and Data collection

The sample size was calculated as follows (Magnani, 2015).

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

Where:

n= required sample size

t = confidence level at 95 per cent (standard value of 1.96)

p = percentage of respondents' knowledge, attitude and practices on riparian degradation estimated at 30%

m = margin of error at 5 per cent (standard value of 0.05)

Therefore:

$$n = \frac{1.96^2 * 0.07(1-0.07)}{0.05^2}$$

$$= 100.03$$

Based on this, a total of 100 respondents/households were selected, 20 in each Water Resource Management Zone (Kaiti River Water Resource User Associations (WRUA) boundaries) owing to the homogeneity of the region in population density and approximate area covered (GOK, 2013). This was approximately 10% of the total number of households within each WRUA boundary which is further recommended by Woolsey, (1956). The five Water Resource User Association have covered the watershed from the catchment down to its outlet. Kivani WRUA occupies the upstream, Upper Kaiti WRUA and Ngutwa Nduenguu WRUA occupy the middle reach while Mbimbini WRUA and Kaiti Kambi WRUA occupy the downstream.

Simple random sampling was used in household questionnaire administration. According to Levy and Lemeshow, (2013), any sample from a population can be chosen and in addition, is as likely to be chosen as any other sample in simple random sampling. Household data was collected using an open and closed-ended questionnaire. Interviews to collect data were done in Kamba dialect to respondents of 18 years and above. A hundred questionnaires were filled out.

Three focus group discussions (FGDs) were held with three independent self-help groups at the upstream, middle reach and downstream to validate household data. These groups were purposefully selected from WRUAs which formed sampling clusters along the riparian zone. The upstream was represented by Kivani SHG (a member of Upper Kaiti WRUA); the middle reach was represented by Mukuyuni SHG (a member of Ngutwa Nduenguu WRUA), while the downstream was represented by Ngitini SHG (a member of Mbimbini WRUA).

Seven key informants were purposefully selected from relevant government and non-government institutions to validate data collected from households and FGDs. The following government institutions were interviewed as key informants: Department of Lands, Urban Development, Environment and Climate Change, Department of Water and Sanitation, Makueni Sand Conservation and Utilization Authority, Kenya Forest Service, Water Service Board, and WRMA. Additionally, one non-governmental organization, Preserve Africa Initiative, was also interviewed. The key informants were selected based on how frequently they directly interact with the riparian ecosystem, formally or informally, and their potential influence on governance of the riparian resources.

A botanical study using presence-absence assessment of the plant species along the river was done to identify key indicator plant species. In identifying key indicator species, a line transect along the Kaiti River was used as the sampling framework as described by Natta (2003). Five points of the transect covering upstream, middle and downstream were sampled. The full transect was 76km with the sampling points occurring at intervals of approximately 15km. At each sampling point observations were made within the river course and 50 meters from the riverbanks. Horizontal digital photographs of characteristic vegetation types along the transect at each site were taken. These were taken across the river to represent both banks for records. Maps were provided by Courtesy of Preserve Africa Initiative who had earlier mapped the watershed.

3.5 Data Analysis and Interpretation

Several standard mathematical and statistical tools were used in data analysis on the SPSS software platform and Microsoft Excel sheet. SPSS version 26.0 was used to run a simple analysis of percentage representation per factor as well as run correlation analysis and Chi-Square goodness of fit. Correlation analysis was used to draw statistical relationships between socio-economic factors and degradation. Simple and Logistic regression models were used to show the level and significance of the relationship between the dependent variables and the independent variables. Riparian degradation was the key dependent variable while Parameters selected to represent causes and effects were the key independent variables.

Simple regression model:

$Y = \alpha + \beta_1 X_1 + ẹ$

Whereby:

Where Y= Dependent Variable (Degradation)

α = Regression Constant

β_1= Beta coefficient

X = independent variable

ẹ= error value (unaccounted factors)

Logistic regression model:

$P = e^{(\alpha + \beta X)/} / (1 + e^{(\alpha + \beta X)})$

Whereby:

Where P= the probability of an event happening

e= natural logarithm, which is equal to 2.718281…….

α and β= the model coefficients

x = independent variable

For median calculation on the questions based on the Likert scale, the following formula was used.

$$Median(M) = L + \frac{\frac{n}{2} - cf}{f} . c$$

Whereby:

L = lower boundary point of median class

n = Total frequency

cf = Cumulative frequency of the class preceding the median class

f = Frequency of the median class

c = class length of median class

A presence-absence analysis was done for the indicator plant species, for those associated with human disturbance, and for those associated with high moisture content in the area. This was done with the help of a botanist. Leaves, and stem characteristics were used as key identifiers of the different species.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter presents the analysis, presentation, and interpretation of findings on the data collected during the study. The first section of the chapter presents the demographic characteristics of the respondents including age, gender, level of education, marital status, household size, occupation, income level, land acreage owned, land segregation and the household proximity to Kaiti River. The second part presents the findings on the socio-economic factors contributing to riparian ecosystem degradation in the Kaiti River riparian zone while the third and fourth present the effects of riparian ecosystem degradation and the indicators of degradation respectively.

4.2 Demographic Characteristics of the Respondents

The survey results show that most of the respondents who participated were female 67.0% while men were 33.0%. The study revealed that most of the respondents (44.0%) were above 59 years old, followed by people aged between 40-49 years (23.0%), 50-59 years (19.0%), 30-39 years (11.0%) and 18-29 years (3.0%). Most of the respondents were recorded as married (89.0%), followed by the single (9.0%) and the widowed (2.0%). The study further shows that the majority of the respondents had a primary school education level [46.0%], followed by those with secondary school education (27.0%), those without formal education (22.0%), college (4.0%) and those who attained university education at (1.0%).

The majority of the households (51.0%) had 4 to 6 members while the biggest household had more than 10 members (6.0%). The study showed that 98.0% of the respondents practiced agriculture as their main occupation, followed by businesspeople (1.0%), and the employed/salaried (1.0%).

Majority of the respondents (97.0%) own between 0-10 acres of land, followed by those who own 11-20 acres (2.0%) and 31-40 acres (1.0%). The survey results show that most of the respondents earned between Kshs 0-300,000 (95.0%), and Kshs. 300,000- 700,000 (4.0%). The majority of the respondents (90.0%) lived approximately less than 3km from Kaiti River, with 59.0% of the respondents living within less than 1km of the river. Those living at 3-5 km represented 10.0% of the respondents. The demographic findings are summarised in Figure 4.1 below.

Figure 4.1: A sunburst chart showing distribution of demographic characteristics among respondents in the Kaiti River watershed.

4.3 Evidence of riparian degradation in Kaiti River

This study sought the opinion of residents on the degradation status of the Kaiti River riparian ecosystem. All the respondents (100%) agreed that the Kaiti River riparian ecosystem is degraded (Table 4.1). An analysis of the data gave a median of 4.56 falling under the strongly agreed category. This was confirmed by one of the key informants who highlighted that there was a lot of illegal human activity especially farming along the riparian zone of Kaiti River. The same was echoed strongly in the FGDs whereby all participants agreed to the fact that the river resource had been degraded over the years. At least 99.0% of the respondents agreed that degradation had highly impacted the river resource. Only 1.0% of the respondents believed that degradation had not affected the river resource (Table 4.1). An analysis of the Likert scale gave a median of 4.3818 falling under the agreed category.

The study sought to know from the respondents the approximate period that degradation accelerated in the river. 40.5% of the respondents stated that it was from the 1990s, 26.6% in the 2000s, 17.7% from the year 2010, 11.4% in the 1970s and 3.8% had no idea (Table 4.1). A calculation of the median with the years put in scale showed that degradation may have accelerated in the 1990s. The majority of the key informants said that there had been gradual increment in degradation but noted that any occurrence of extremity in rainfall intensity like in the case of 1998 and 2018 has led to a surge in the rate of degradation with some cases leading to serious humanitarian crisis (loss of property and lives). The FGD participants agreed that degradation was gradual over time dating back to the 1970s as much as they know but seems to have been accelerated by the 1998 *El-nino* and another heavy downpour in 2014.

Further, the study also sought to know the features or occurrences the locals would consider as general signs of degradation in the river. The findings (Table 4.1) show that the majority of the respondents referred to eroded riverbanks within the riparian zone as a major evidence of degradation 36.3%. Vegetation loss within the riparian zone followed with 26.0%, exposed rocks at 21.8%, dry riverbeds at 8.0%, vanishing of wildlife once noticed in the riparian zone at 3.8% and dried wells had 3.4%. Data analysed from key informants and Focus groups pointed to loss of trees/vegetation, reduced population of animals like birds, falling and exposed riverbanks and rocks, increased speed of water, water becoming dirtier, widening of rivers; sand composition; exposed rocks and drying aquifers as some physical evidence of riparian degradation. Other evidence mentioned by key informants and FGD participants included drying river wells, reduced income levels from riparian land investments and resource conflicts. Observation made along the Kaiti River during the study depicted freshly fallen river walls, gullies and recently cut tree trunks (Plate 4.1 & 4.2).

Table 4.1: Respondents' opinions on presence, significance, and evidence of riparian degradation in the Kaiti River

Parameters	**Categories**	Number of Respondents	**Percentage**	Cumulative frequency	**Mean % (f)**	**Median**
n = 100			**% (f) (n = 100)**	*Cf*		
Presence of Degradation	Strongly disagree (1)	0	0	0	4.5377	4.5698
	Disagree (2)	0	0	0		
	Neither (3)	0	0	0		
	Agree (4)	44	44.0	44.0		
	Strongly Agree (5)	56	56.0	100.0		
Impact on the River course	Strongly disagree (1)	0	0	0	4.3772	4.3818
	Disagree (2)	0	0	0		
	Neither (3)	1	1.0	1		
	Agree (4)	58	58.0	59		
	Strongly Agree (5)	40	40.0	100		
Period when degradation accelerated	Don't know (1)	3	3.8	3.8	3.815	3.9495
	1970 – 1979 (2)	9	11.4	15.2		
	1980 – 1989 (3)	0	0	0		
	1990 – 1999 (4)	32	40.5	55.7		
	2000 – 2009 (5)	21	26.6	82.3		
	2010 – present (6)	14	17.7	100		
Evidence of degradation	eroded river banks	95	36.3%	36.3		
	dry river beds	21	8.0%	44.3		
	exposed rocks	57	21.8%	66.1		
	vegetation loss within the riparian zone	68	26.0%	92.1		
	vanishing of wildlife once noticed in the riparian zone	10	3.8%	95.9		
	dried wells	9	3.4%	99.3		
	Others	2	0.8%	100		

Plate 4.1: Kaiti River eroded river banks at Mwaani section

Plate 4.2: Kaiti River dry river floor, exposed rocks and little vegetation

4.4 Causes of Riparian Degradation

The study sought to determine the socio-economic factors contributing to riparian ecosystem degradation in the Kaiti River riparian zone. The household questionnaire focused on five potential causes presented from sub-sections 4.4.1 to 4.4.5. Similar causes were highlighted by key informants and FGDs who without rating mentioned the key causes of degradation to be settlement and farming in riparian areas, population growth and economic crisis, natural catastrophes, uncontrolled commercial sand harvesting and human overreliance on natural resources. The FGDs emphasized on clearing of trees near the river for agricultural purposes and poor farming practices which include poor or lack of terracing, lack of cover crops and farm grazing during dry seasons. The study team made several river visits and made observations ranging from tree felling and charcoal making, brick-making activities and cattle grazing along riverbanks (Plate 4.3).

Plate 4.3: Observed potential causes of riparian degradation on Kaiti River riparian zone (charcoal making, Irrigation sand harvesting-right)

4.4.1 Riparian Conservation Awareness

4.4.1.1 Level of understanding on riparian ecosystem conservation

The findings (Table 4.2) revealed that the majority of the respondents rated their understanding of riparian ecosystem conservation fairly (36.7%), poorly (29.6%), good (22.4%), very poor (7.1%) and excellent (4.1%). An analysis of the data gave a median of 3.095 falling under *the Fair* understanding category. From the FGDs, it was evident that some of the group members had a fair understanding of riparian degradation and natural resource conservation.

Table 4.2: Level of understanding on riparian ecosystem conservation by respondents.

Research Parameters	**Categories**	Number of Respondents	**Percentage**	Cumulative frequency	**Median**	**Sig**
n = 100			**% (f) (n = 100)**	*Cf*		
Level of Awareness	Very poor (1)	7	7.1	7.1	3.095	0.002
	Poor (2)	29	29.6	36.7		
	Fair (3)	36	36.7	73.4		
	Good (4)	22	22.4	95.8		
	Excellent (5)	4	4.1	100.0		

4.4.1.2 Membership to Water Resource User Association

The majority of the respondents (70.0%) do not belong to any WRUA while 30.0% belonged to at least one WRUA (Figure 4.2). A correlation analysis showed that membership to WRUAs had a positive correlation (r= 0.605, p<0.05) with Riparian conservation awareness and participation indicating that more membership to WRUAs would result in better riparian system conservation. Marital status (r= -0.172, P= 0.091), level of income (r= -0.093, P= 0.358), distance from Kaiti River (r= -0.073, P= 0.472), gender (r= -0.042), age (r= -0.019, P=0.854) and level of education (r= -0.076, P = 0.635) were found to have negative but insignificant correlation with membership to WRUAs. Occupation of the household head (r= 0.092, P= 0.364) on the other hand had a positive but insignificant correlation with membership to WRUAs.

A rough count at the FGD meetings realized that 73.21% of group members were members of WRUAs. Their membership was high because the groups had firm associations with WRUAs. The members added that through the WRUAs they had benefitted from livelihood skills training, soil erosion control by building gabions as well as construction of dams which have increased access to water.

4.4.1.3 Participation in Kaiti river's community conservation activities

The study showed that 54.2% of the respondents have participated in one or more than one of Kaiti River's community conservation activities while 45.8% have not (Figure 4.2).

4.4.1.4 Training on Conservation Practices

The study findings (Figure 4.2) show that 84.5% of the respondents have received training on conservation practices while 14.4% have not. The FGDs added that these trainings had mainly come through their WRUAs and had increased their awareness of Riparian ecosystem conservation.

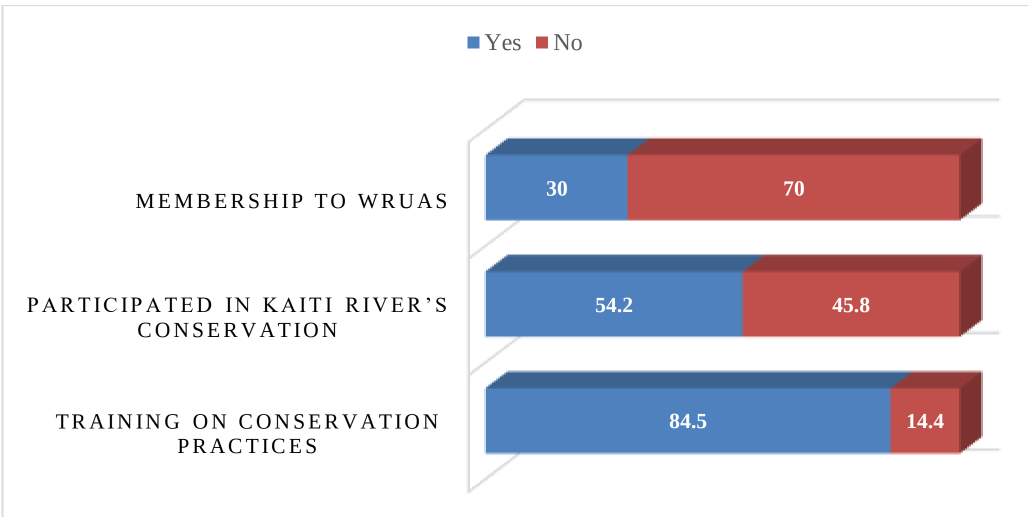


Figure 4.2: Membership to (WRUAs), participation in Kaiti River conservation activities and training on Conservation

4.4.1.5 Institutions responsible for the riparian conservation training received

The study went further to find out who was responsible for the riparian conservation training received by the respondents. Results in Table 4.4, show that CSOs, (NGOs, Churches, CBO and Networks) at 52.0% trained the majority of the respondents, followed by the government (23.0%), and the private sector (business partners e.g agrochemicals industries) at 16.0%. At least 2.0% of the respondents did not have any idea of any institution responsible for the riparian conservation training.

Table 4.3: Percentage of who have been responsible for trainings received.

Institutions responsible for training	Frequency	Percent (%
The government	23	23.0
CSOs, [NGO, Churches, CBO, Networks, etc]	52	52.0
The private sector (business partners e.g agrochemicals industries	16	16.0
Others	2	2.0

A logistic regression model was used to test the significant effect of riparian conservation awareness on degradation. The table below (Table 4.5) shows a logistic regression model on the impact of riparian ecosystem awareness on degradation. From the table, it was found that riparian ecosystem conservation awareness significantly affected degradation (P-value= 0.002).

Table 4.4: Model coefficients for impact of riparian ecosystem awareness on degradation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	how would you rate your understanding of riparian ecosystem conservation	-.757	.241	9.865	1	.002	.469
	Constant	2.398	.737	10.597	1	.001	11.002

a. Variable(s) entered on step 1: how would you rate your understanding of riparian ecosystem conservation?

The Model fitted is:

$$P = e^{2.398 - 0.757x}/(1+e^{(2.398 - 0.757x)})$$

This indicates that for every unit increase in the riparian ecosystem conservation awareness, there will be a 0.757-unit reduction in the level of degradation in the Kaiti River riparian zone.

4.4.2 Crop farming

The study showed that fruits [mangoes, avocado, and oranges pawpaw] are the main crops grown by respondents in their farms as represented by 62.0%, cereals and legumes [maize, beans, peas, green grams] at 31.0% followed by root tubers at 7.0% (Figure 4.3).

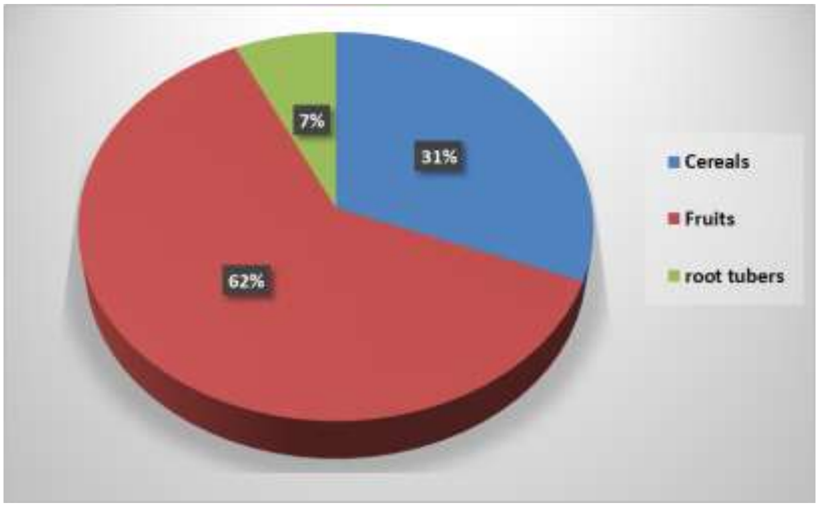


Figure 4.3: Distribution of crop cultivated in the Kaiti River watershed.

The study (Table 4.6) showed that the majority of the respondents had established agro-forestry systems in their farms. Majority of the respondents (35.0%) practice windbreakers, followed by intercropping 31.0%, boundary planting agroforestry system (21.0%), planting of terraces 2.0% and alley cropping (1.0%). These systems were practised by farmers irrespective of the type of crop cultivated.

Table 4.5: Percentage of agro-forestry systems used in farms.

Agroforestry system used	No. of respondents	Per cent
windbreakers	35	35.0
Intercropping	31	31.0
boundary system	21	21.0
alley cropping	1	1.0
planting on terraces	2	2.0
Others	4	4.0
None	6	6.0

The majority of the respondents (48.0%) use organic manure for soil fertility management followed by inorganic fertilizers (47.0%) and cover crops (5.0%) (Figure 4.4).

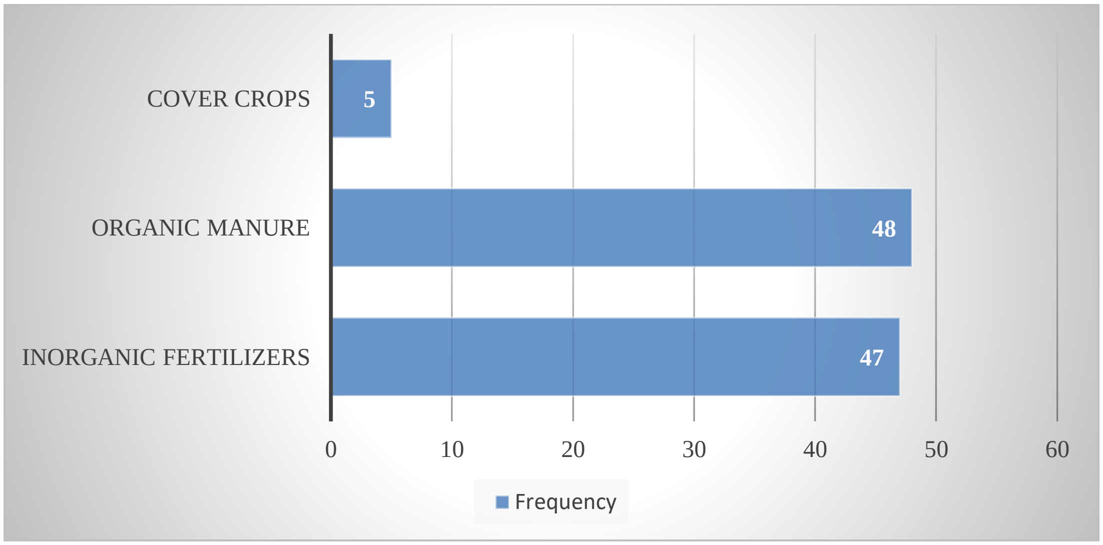


Figure 4.4: Soil fertility management practices applied in the area

A simple regression test was used to test crop farming's contribution to degradation. The analysis tested if crop farming had contributed significantly to the degradation of the Kaiti River riparian ecosystem. The results of the regression model are presented in Table 4.7 below.

Table 4.6: Regression results for crop farming against degradation

	Beta Coefficient	R	R Square	F	P – value	Hypothesis Supported
Farming Practices	0.782	.921[a]	.849	9.4495	0.0003	Yes

The results of the study show a significant relationship between farming and the degradation of the Kaiti River riparian ecosystem $F(1, 99)=9.4495$, $p \leq 0.05$, which indicates that crop farming plays a significant role in shaping the degradation of the Kaiti River riparian ecosystem ($\beta=0.782$, $p<0.05$). Moreover, the R^2 value of 0.849 depicts that the independent variables (crop farming) account for 84.9% of the variations in the degradation of the Kaiti River riparian ecosystem.

Among the specific farming practices contributing to riparian degradation, farming on steep slopes was ranked top as reported by 51.7% of the respondents, followed by farming along the riparian zone (36.1%) and settlement in river catchment (10.2%) (Table 4.8). Interaction with key informants concurred with the household survey findings pointing out that farming is one of the major causes of riparian degradation. They pointed out that the effects of crop farming are further aggravated by poor farming methods and a lack of understanding and awareness of the existing policies. The FGD participants highlighted that crop farming is the main cause of large tree felling to clear land for cultivation which leads to loss of vegetation hence exposing soils to agents of soil erosion and weakening the soil structure.

Table 4.7: Farming practices contributing to Kaiti River riparian degradation.

Farming Practices	No. of respondents	Per cent	Chi-square sig.
Farming on steep slopes	76	51.7%	0.487
Settlement in river catchment	15	10.2%	0.028
Farming along the riparian zone	53	36.1%	0.563
Others	3	2.0%	0.949

4.4.3 Livestock Farming

The study sought to identify the common livestock feeding practices to give insight into livestock farming's potential for riparian degradation. Tethering was the leading method of livestock farming as represented by 65.0%, followed by zero grazing (31.0%) and free-range grazing (1.0%), (Table 4.9). Correlation analysis indicated a positive but insignificant relationship between the number of cattle and the method of livestock farming used (r= 0.062, P= 0.555).

Table 4.8: A distribution of Livestock farming methods

Parameter	Frequency	Per cent
zero grazing	31	31.0
Tethering	65	65.0
free grazing in the field	1	1.0
Others	1	1.0

It was revealed that 48.5% of the respondents didn't have enough pasture to graze cattle throughout the year while 51.5% had. To cope with the feed deficit, buying pasture from neighbours was the most sought alternative reported by 42.0% of the respondents, followed by grazing on the riverside (8.0%), buying from rangelands 2.0% and buying from agro-shops (1.0%) (Table 4.10).

Table 4.9: Additional ways of getting pasture for grazing throughout the year

Alternative sources of feed for cattle	Frequency	Per cent
Buying from neighbours	42	42.0
Buying from rangelands	2	2.0
Buying from agro-shops	1	1.0
Grazing on the riverside	8	8.0
Have sufficient	50	51.5

A simple regression test was used to test livestock farming's contribution to degradation. The analysis tested if livestock farming had contributed significantly to the degradation of the Kaiti River riparian ecosystem. The results of the regression model are presented in Table 4.11 below.

Table 4.10: Regression results for livestock-keeping practices against degradation

	Beta Coefficient	R	R Square	F	P – value	Hypothesis Supported
livestock Keeping	0.211	.784[a]	.615	0.096	.002[b]	Yes

The results of the study showed that livestock farming significantly contributed to the riparian degradation of the Kaiti River, $F(1, 99)=0.096$, $p<0.05$, which indicates that livestock farming plays a significant role in shaping the degradation of the Kaiti River riparian ecosystem ($\beta=0.211$, $p<0.05$). Moreover, the R^2 value of 0.615 depicts that the independent variables (livestock farming) account for 61.5% of the variations in the degradation of the Kaiti River riparian ecosystem.

Interaction with key informants and FGDs corresponded with the above findings suggesting that livestock grazing contributes to degradation along the riparian zones. They indicated that grazing along the riparian areas leads to the destruction of indigenous trees and loss of vegetation cover, weakening soil structure and leading to the collapse of riverbanks. They indicated that poor methods of grazing like overgrazing amplified these effects.

4.4.4 Commercial Sand Harvesting

This study sought to know from the respondents if they were aware of commercial sand harvesting activities in Kaiti River and their opinion of it being a contributing factor to the river's degradation. At least 58.0% of the respondents reported that they were aware of commercial sand harvesting along the river, 41.0% said there was no commercial sand harvesting practised along Kaiti River and 1% had no idea. Among those agreeing that there was commercial sand harvesting ongoing, 59.7% believed it had slightly contributed to degradation, 27.8% believed its impact was great while 12.5% thought it had no effect (Table 4.12).

Table 4.11: Sand harvesting magnitude and effect on the Kaiti River riparian ecosystem

	Parameter	Frequency	Per cent
Is sand harvesting happening	Yes	58	58.0
	No	42	42.0
	No idea	1	1.0
Effect of Commercial Sand Harvesting	Greatly degrading	20	27.8
	Slightly degrading	43	59.7
	No effect	9	12.5

A simple regression test was used to test sand harvesting's contribution to degradation. The analysis tested if sand harvesting had contributed significantly to the degradation of the Kaiti River riparian ecosystem. The results of the regression model are presented in Table 4.13 below.

Table 4.12: Regression results for sand harvesting against degradation

	Beta Coefficient	R	R Square	F	P – value	Hypothesis Supported
Sand harvesting	0.205	.812[a]	.659	21.572	.000[b]	Yes

The results of the study showed that sand harvesting significantly contributed to the riparian degradation of the Kaiti River, $F(1, 99)=21.572$, $p<0.05$, which indicates that sand harvesting plays a significant role in shaping the degradation of the Kaiti River riparian ecosystem ($\beta=0.205$, $p<0.05$). Moreover, the R^2 value of 0.659 depicts that the independent variables (sand harvesting) account for 65.9% of the variations in the degradation of the Kaiti River riparian ecosystem.

There was a general view with key informants that the rate of commercial sand harvesting had been high but was on a decline, especially after the ban by the County government and the subsequent sand harvesting regulations. The interaction with one key informants pointed out that the Makueni County Government had in 2015 enacted the Makueni County Sand Conservation and Utilization Act placing commercial sand harvesting under the custody of Makueni County Sand Conservation and Utilization Authority. This was seen to have greatly influenced the scope and criterion of commercial sand harvesting along the Kaiti River since then. The FGDs also pointed out the recent enactment which has eased the situation. They underlined the fact that sand harvesting leads to weakened riverbanks, early drying of riverbeds, water becoming dirtier, and the heavy trucks loosening soil along the paths they use leading to soil erosion.

4.4.5 Other Causes of Degradation

The study went further to investigate other causes of degradation in the Kaiti River ecosystem besides the ones projected in the study. The results of the study found that poor natural resource governance was a major cause of riparian degradation rated at 30.0%, poverty at 25.4%, poor infrastructure (19.0%) and climate change (20.4%) (Table 4.14).

Table 4.13: Other causes of degradation in the Kaiti River riparian ecosystem.

Other Causes of riparian degradation	Frequency	Per cent
poor natural resource management/governance	44	31.0%
Poverty	36	25.4%
Infrastructure	27	19.0%
climate change	29	20.4%
Others	6	4.2%

The key informants referred to activities resulting from climate change like floods, high rain intensity and prolonged droughts as other serious causes of degradation along riparian zones. They, however, added that climate change was a manifestation (a long-term effect) of past day-to-day human activities.

The key informants highlighted the issue of land use change as a major cause of degradation. Some of the land use changes mentioned were over-reliance on land, settlement in riparian zones, land subdivision and fragmentation and the preference to farm near rivers for better productivity. These land use changes lead to tree felling and loss of vegetation cover, soil erosion, widening riverbanks and water contamination. They also highlighted deforestation as a major cause of degradation resulting from human activities like charcoal burning, kilning of bricks and building materials like timber and poles.

A simple regression test was used to test the contribution of these causes to degradation. The analysis tested if these causes had contributed significantly to the degradation of the Kaiti River riparian ecosystem. The results of the regression model are presented in Table 4.15 below.

Table 4.14: Regression results from other causes of degradation

	Beta Coefficient	R	R Square	F	P – value	Hypothesis Supported
Sand harvesting	0.212	.721[a]	.520	0.086	.001	Yes

The results of the study showed that the above-mentioned causes of degradation significantly contributed to riparian degradation of the Kaiti River, $F(1, 99)=0.086$, $p<0.05$, which indicates that they play a significant role in shaping the degradation of the Kaiti River riparian ecosystem ($\beta=0.212$, $p<0.05$). Moreover, the R^2 value of 0.520 depicts that the independent variables (other causes) account for 52.0% of the variations in the degradation of the Kaiti River riparian ecosystem.

4.5 Effects of riparian degradation

The survey results show that riparian degradation of the Kaiti River had a significant effect in the region ($p=0.000 \leq 0.05$) with 88.9% of the respondents reporting to have been affected by degradation of the Kaiti River in one way or the other. At least 74.7% of the respondents reported that degradation had affected their crop farming while 84.6% of the respondents reported that degradation had affected their livestock keeping. At least 75.6% of the respondents reported that degradation had affected access to water for domestic use while 96.7% reported that degradation had affected the Kaiti River’s aesthetic value. At least 97.8% of the respondents agree that degradation had affected wildlife in the riparian zones and affected the community socio-economically (Figure 4.5). From the FGDs, the participants unanimously agreed that they had been affected by the Kaiti River riparian degradation.

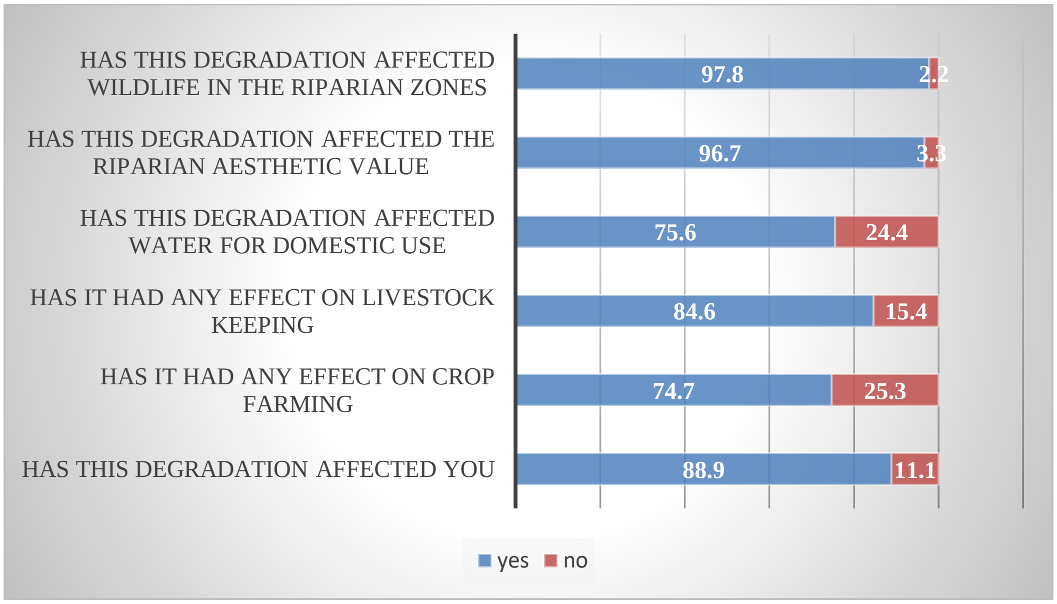


Figure 4.5: Levels of different effects due to Kaiti River degradation

4.5.1 Effects of degradation on crop farming

Degradation of Kaiti River was found to have a significant effect on crop farming (ß =0.3, t=3.647, p value=0.003$\leq$ 0.05) with the main effect being reduced supply of water for irrigation reported by 59.7% of the respondents, followed by reduced productivity for river irrigated farms (19.4%), poor riverine soils (11.9%) and poor-quality water for irrigation (4.5%) (Table 4.16). The above findings were also highlighted by the key informants who indicated that degradation had led to low yields from irrigated farms and insufficient water for irrigation. The FGDs pointed out poor land productivity due to soil erosion.

A logistic regression model was used to determine the nature of the effect of degradation on crop farming which indicated that reduced supply of water for irrigation was the most significant effect that degradation had on crop farming (P-value= 0.015<0.05).

Table 4.15: Effects of riparian degradation on crop farming

Effects on crop farming	Frequency	Per cent	Sig
reduced supply of water for irrigation	40	59.7	0.015
poor riverine soils	8	11.9	.416
poor quality water for irrigation	3	4.5	.999
reduced production for river-irrigated farms	13	19.4	.999
Others	3	4.5	.999

4.5.2 Effects of degradation on livestock keeping

The effect of degradation on livestock keeping was found to be significant (ß =0.384, t=4.289, p value=0.001≤ 0.05) with reduced watering points for livestock being the main degradation effect on livestock keeping (62.8%), followed by reduced alternative fodder sources (32.1%), increased fodder cost (2.6%) and increased cost of water for zero grazing (2.6%) (Table 4.17).

A logistic regression model was used to identify the nature of the effects on the specific livestock-keeping factors. Reduced fodder sources were identified to be the most significant effect that degradation had on livestock keeping (P-value= 0.012).

The key informants and FGDs also highlighted that degradation had led to reduced availability of water for livestock, lack of enough fodder and increased cost of fodder. They added that water and fodder scarcity had made livestock keeping more time-consuming and uneconomical.

Table 4.16: Degradation effects on livestock keeping

Effect on Livestock keeping	Frequency	Per cent	Sig
reduced fodder sources	25	32.1	.012
reduced alternative grazing land during droughts	2	2.6	1.000
reduced watering points for livestock	49	62.7	.997
increased fodder cost	2	2.6	.999

4.5.3 Effects of degradation on water for domestic use

The effect of degradation on water for domestic use was found to be significant (p value=0.001$\leq$ 0.05) with reduced availability of clean water for washing and cooking being the main effect at 75.4%, followed by reduced availability of clean water for drinking at 21.7%, increased waterborne diseases at 2.9%% (Table 4.18).

A logistic regression model was used to determine the nature of the effect on water for domestic use. It was identified in the model that degradation significantly reduced the availability of clean water for washing and cooking (P-value= 0.004$\leq$ 0.05). The key informants and FGDs confirmed that degradation had led to the unavailability of both clean and enough water for domestic use.

Table 4.17: Degradation effects on water for domestic use

Effect on water for domestic use	Frequency	Per cent	Sig
reduced availability of clean water for washing and cooking	52	75.4	.004
reduced availability of clean water for drinking	15	21.7	.998
increased waterborne diseases	2	2.9	.999

4.5.4 Effects of riparian degradation on biodiversity and Socio-economic conditions

It was revealed that the effect of degradation on biodiversity was highly significant (ß =0.407, t=5.001, p value=0.000$\leq$ 0.05) according to the regression model. Among the effects on biodiversity, reduced riparian vegetation cover was leading as represented by 68.5%, followed by reduced variety of birds at 6.7%, changed vegetation cover at 6.7%, and reduced water pools at 4.5% (Table 4.19).

A logistic regression analysis pointed out reduced vegetation cover as the most significant effect on biodiversity ($p=0.009<0.05$). Reduced bird varieties were also found to be significant. The interaction with key informants pointed to compromised riparian biodiversity and aesthetic value because of degradation. The key informants indicated that degradation had a negative impact on both the quantity and quality of biodiversity as well as on the economy. They also indicated that degradation had led to conflicts interfering with social cohesion; loss of lives; high cost towards the maintenance of infrastructure and even land value change. The FGDs highlighted increased water-related diseases as well as loss of land due to river widening.

Table 4.18: Riparian degradation on biodiversity and socio-economic conditions.

Effect on river's aesthetic value	Frequency	Per cent	Sig
Reduced riparian vegetation cover	61	68.5	.009
changed vegetation cover	6	6.7	.407
reduced variety of birds	6	6.7	.000
reduced water pools	4	4.5	.555
Others	12	13.5	.347

4.6 Degradation Indicators

4.6.1 General degradation indicators

The study intended to establish whether there existed reliable general indicators of degradation along the Kaiti River which could be used for monitoring purposes. The study revealed that physical indicators exist to show degradation (p-value $=0.000\leq0.05$). At least 44.1% of the respondents identified the disappearance of bird species as a major indicator of riparian degradation followed by a change of vegetation at 38.0%, reduced water flow at 12.3%, and disappearance of fish species at 5.6%. (Table 4.20). A Chi-Square Test identified the disappearance of bird species as a significant indicator of degradation.

Table 4.19: General indicators of riparian degradation.

General degradation indicators	Frequency	Per cent	Chi Sq Sig.
Change of vegetation	68	38.0%	0.502
Disappearance of bird species	79	44.1%	0.029
Reduced water flow	22	12.3%	0.233
Disappearance of fish species	10	5.6%	0.074

4.6.2 Riparian degradation plant indicators

A botanical study of the Kaiti River floor and riparian zone at the five points along the river transect revealed reliable plant indicators both for riparian degradation and high-water table. Of these, 10 degradation indicator plant species and 5 high water table plant indicator species were identified as listed in tables 4.21 and 4.22 below. High water table plant indicators were sought to identify remnants of a healthy riparian vegetation population slowly disappearing due to riparian degradation.

Table 4.20: Degradation plant indicator species observed

S/No	Plant species	Kamba Name
1	*Euphorbia schefflera*	Kilembwa
2	*Balanites aegyptiaca* (L.) Delile.	Kilului
3	*Acacia tortilis* (Forssk.) Hayne.	Muaa
4	*Lantana camara* L.	Mutavisi
5	*Croton dichogamus* L.	Muthinia
6	*Ipomoea kituiensis* Vatke.	Ilaa
7	*Nicotiana glauca* (Graham) Griseb.	Mbaki ya Kithekani
8	*Combretum molle* R.Br. ex G.Don.	Kiama
9	*Combretum collinum* Fresen.	Itiithi
10	*Schkuhria pinnata* (Lam.) Kuntze ex Thell.	Kamukununi

Table 4.21: High water table indicator species that were observed.

S/No	Plant species	Kamba Name
1	*Acacia elatior* Brenan.	Munina
2	*Kanahia longiflora* (Forssk.)	Kamunywa Manzi
3	*Ficus sycomorus* L.	Kikuyu
4	*Acacia polyacantha* (Willd.)	Kiseleele
5	*Phragmites mauritianus* Kunth.	Muangi/kiisi

CHAPTER FIVE

5.0 DISCUSSION

5.1 Demographic characteristics and degradation

Results from this study indicate a low level of education in the Kaiti River riparian zone which would mean a low status of living according to a study by Abuya, Ciera, & Kimani, (2012) who established that education and knowledge are key factors determining the living status of households. World Bank (2014) adds that a farmer's decision to adopt new technologies is subject to the level of education received which in turn influences their socio-economic growth. The data on the level of income validated the assumptions further since majority of the respondents had an income level of below 100,000 per annum which was low as per the UNDP, (2015) Human development report statistics. This was supported by Kieti et al, (2016) who said that limited access to formal employment was due to low levels of education and low levels of income are expected to lead to high dependency on natural resources for livelihoods and subsequent natural resource degradation.

The study found that most of the respondents were over 60 years of age which means that it is the aged who are less energetic that are available to implement community conservation projects in the area. This limits the extent to which they can successfully ensure that conservation activities are implemented. The absence of the youth may also mean shortage of creative and new ideas. Mwei, (2016) states that young people can provide basic knowledge and perspectives on development that adults cannot provide because they have experience, knowledge, understanding, and concepts that are specific to their circumstances. Mwei, (2016) adds that in many communities, youth make up much of the population; as a result, youth voices can be crucial expressions of entire community needs; Mwei's study further says that young people's participation in community development can increase their self-esteem and connections with peers and communities. Correlation analysis did not show any relationship between age and membership to WRUAs which indicates that membership is open to all ages, but the youth's unavailability as seen in the respondent tally may be replicated in WRUA membership and its activities. Hodge, (1968) says that Parental involvement in such groups appears to have at least as much of an impact on a respondent's decision to join a voluntary organization as does their socioeconomic condition.

To understand further the factors affecting membership to WRUAs, correlation analysis revealed that there was no statistically significant association between being a member of to of water resource user's association and occupation of the household head, gender, age or level of education. This means that membership was welcoming and favourable to people of all occupations, genders, and education levels. In a study on the performance of WRUAs in Kibwezi Ndeti, (2013) recommended that WRUA membership should be representative and diverse and, depending on the main activities in a catchment, the different water utility groups should be represented. There was a relationship between marital status and being a member to a WRUA meaning that the married were most likely to join the WRUA. The Negative relationship between distance of household from Kaiti River and membership to a WRUA meant that those living far from the river were less likely to become members.

Households mainly belonged to the married with the majority of family sizes ranging from 4 to 6 members and the largest household having more than 10 members. This means continued subdivision of land and consequently more pressure on natural resources as well as more land being turned to agriculture. Most respondents own less than 10 acres of land, meaning they are small-scale farmers, according to FAO (2013) farmer classifications. Wanyama, Masinde, & Obare, (2013), argue that large-scale agriculture influences the adoption of better agricultural technologies. The larger the farm, the more land it can distribute and the more likely it is to adopt new crops and new techniques. Therefore, small land ownership would limit the practising of conservation technologies like agroforestry and thus continued degradation.

The majority of the respondents live and farm within less than 1 km from Kaiti River which indicates existing and potential human pressure on the river resource which would be detrimental if not controlled. A study by Olokeogun et. al., 2020, on the vulnerability of riparian ecosystems to human settlement found that vulnerability was highest in the high-density settlement areas of riparian zones.

5.2 Evidence of riparian degradation

The present study strongly confirmed that degradation has been happening in the Kaiti River riparian ecosystem with all the respondents agreeing to this fact. This was well evidenced by eroded riverbank vegetation loss within the riparian zone, exposed rocks, and dry riverbeds. Richardson et. al, (2007) agrees that riparian degradation will largely be evidenced by changes in vegetation, water flow and water quality among others. Key informants and Focus groups highlighted more evidence including the reduced population of animals like birds and fish, increased speed of water, water becoming dirtier, drying aquifers, reduced income levels from riparian land investments and resource conflicts. Freshly fallen river walls and gullies observed during the study confirmed the claims. The study concluded that degradation had accelerated from the 1990s to 2000 with more suggestions that degradation has been gradual over the years with surges after excessively high rainfall seasons like El nino in 1997. Kieti et al., (2016) confirms this by saying that watershed degradation is a problem in Makueni County as a result of rapid population growth, high poverty levels, land use changes/ poor land use systems and deforestation.

5.3 Causes of riparian degradation

The study showed that the respondents' understanding of riparian ecosystem degradation was fair which according to regression analysis, has a significant influence on the rate of degradation. This agrees with Ndeti, (2013) who found that training which is promoted through village public gatherings has impacted WRUA's water conservation performance in Kibwezi Makueni County. Correlation analysis showed that members of a WRUA were more likely to participate in conservation activities than non-members. Therefore, low membership to WRUA has a significant effect on riparian degradation awareness and community participation towards the conservation of Kaiti River's ecosystem. According to Nyang, Webo & Roothaert, (2010), it is easier when farmers collaborate in small groups during extension programmes, training, demonstration, and visits. However, non-members of WRUAs also participated in conservation activities indicating that there were other avenues or groups through which conservation activities were done besides the WRUAs or that non-members were welcome during conservation activities. However, a study by Mworia et. al, 2019, highlights that WRUAs have not been successful in sustainably managing riparian resources in the Tana Catchment area.

The high conservation awareness in the region can be attributed to both membership to WRUAs and pieces of training offered to those living along the watershed. A study by Thuo et al., (2018) in the Southeastern region of Kenya indicated that 68% of the sample households have soil and water conservation practices in their farms and show soil and water conservation knowledge in the study area. Elsewhere, evidence of rapid adoption of the Land Development Program in Africa has benefited from continued farm-to-farmer training. (Duveskog, Mburu, & Critchley, 2003).

This study showed that crop farming was a leading cause of degradation with farming on steep slopes ranked highest, followed by farming along the riparian zone and settlement in river catchment which is accompanied by farming on site. This was strengthened by key informants and FGDs who pointed out that the effects of farming are aggravated by poor farming methods and lack of understanding and awareness to the existing policies. A related study by Schmitt, Kisangau, & Matheka, (2019) in Kitui County found out that riparian encroachment reached 10 m of the river channel with native riparian vegetation taking only 12% of the riparian area, while farming took upto 52% of the zone in most areas. The FGD participants highlighted that farming is the main cause of largescale tree felling on the riparian zone to clear land for cultivation which leads to loss of vegetation hence exposing soils to agents of soil erosion and weakening the soil structure. This also agrees with a recent study in Ethiopia which pointed out agriculture as a main cause of wetland degradation (Bezabih, et al., 2017). Richardson et. al., 2007 states that cultivation of crops adjacent to the river may increase sediment deposition and eutrophication.

The Kaiti River watershed being an agricultural zone is dominated by fruit farming mainly Mangoes, oranges which is a chemical intensive venture and may be responsible for biodiversity changes in the riparian ecosystem especially loss of fish, birds and insects according to Matano et al., (2015). Mugachia, Kanja & Gitau, (1992) enlists egg-shell thinning in birds and reduced egg hatchability in fish as some of the effects of pesticides used in agriculture in Kenya. However, fruit tree farming may also have a positive impact since fruit trees add to tree cover increasing rain interception and therefore reduced runoff. Fruit farming has been integrated with boundary tree planting and intercropping which has a resultant effect of increased tree cover and less soil erosion (Kamar, 2001). There is also less use of fertilizers and more use of organic manure which is a positive gesture. Use of fertilizer on agricultural land is responsible for increased nitrate load which according to Barker et. al., (2008), the increased nitrate concentrations would result in changes in freshwater systems' productivity or affect to the biodiversity.

The results of the study showed that livestock farming practices significantly contributed to degradation of Kaiti River riparian ecosystem with cattle tethering as the most popular livestock keeping method in the riparian zone. Many of the respondents did not have enough pasture to graze cattle throughout the year meaning that chances of overgrazing in the riparian zone are high. This agrees with a study by Kanga et al., on the Mara region of Kenya who argue that habitats of riparian savanna that are grazed by livestock or hippos undergo seasonal ecological stressors due to the depletion of herbaceous vegetation. Their study indicated heightened grazing in the riparian zone compared to surrounding terrestrial areas. Tethering if not well managed has the effect of overgrazing patches of land leading to exposed soil which further leads to soil erosion consequently silting riparian zones. This is supported by Dada et. al., (2019), who say that the compaction caused by the trampling of animals generally disrupts the soil structure, increases the bulk density, reduces the porosity, reduces the permeability, causes water accumulation in the depression and surface runoff, thus making the land vulnerable to water erosion.

Grazing on the riverside was found to significantly influence the degradation of the Kaiti River riparian ecosystem. Clary, (2000) suggested that the effects of grazing could alter biogeochemical cycles resulting in drastic alterations in riparian vegetation composition and productivity, aquatic systems and water quality. Key informants and FGDs indicated that grazing along the riparian areas leads to destruction of indigenous trees and loss of vegetation cover thus weakening soil structure and leading to collapsing of riverbanks. Overgrazing on the riverside may also cause the extinction of some plant species due to disturbance and introduction of invasive species as supported by Robertson et al. (2000), whose study noted that grazing has altered and continues to alter the structure and function of the riparian landscape in the Murrumbidgee River and its tributaries in southeastern Australia. (Richardson et. al., 2007) also add that grazing trampling affects riparian zones which in turn act as triggers for the proliferation of alien plants.

Sand harvesting was found to be a significant contributor to riparian degradation in the Kaiti River riparian zone. Commercial sand harvesting had been witnessed by the majority of the respondents and further explained by key informants who argued that the rate of commercial sand harvesting is on a decline, especially after the ban by the County government and the subsequent regulation. They emphasized the fact that sand harvesting leads to weakened riverbanks, early drying of riverbeds, and water becoming dirty while the heavy trucks loosen soil along the paths they use. Tractors harvesting sand from the river were observed near Wote town. Ashraf et. al., (2011) says that Environmental problems occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials, and that sand mining affects water quality downstream and the adjacent physical environment.

Besides the hypothesised causes of riparian degradation, poor natural resource management and governance were highlighted as the other major causes, followed by poverty, poor infrastructure and climate change. The study found that these causes were highly significant in the degradation of the Kaiti River riparian ecosystem. The key informants and FGDs indicated that activities resulting from climate change like floods, high rain intensity and prolonged droughts were serious causes of degradation along riparian zones. Perry et al. (2012) concur with this by indicating that riparian ecosystems, already greatly altered by water management, land development, and biological invasion, were further being altered by increasing global warming and climate change, particularly in arid and semiarid (dryland) regions.

The key informants highlighted the issue of land use change as a major cause of degradation. This is confirmed by Mutua, kisangau & Musimba (2019) in their study on the impacts of land use change on dryland biodiversity in Makueni County. Some of the land use changes were overreliance on agriculture, settlement in riparian zones, land subdivision and fragmentation and the preference to farm near rivers for better productivity. Other impactful activities included tree felling for charcoal burning, kilning of bricks and building materials leading to loss of vegetation cover, soil erosion, widening riverbanks and water contamination. Kieti et al., (2016) quote land use changes, rapid population growth, poverty, climate change variability and lack of livelihoods diversification as some of the contributing factors to riparian degradation. Small urban centres have also emerged along the rivers and according to Olokeogun et al. 2020, this is a likely factor putting pressure on the river resources including sand, water and stones as well as introducing more waste to the river.

Upstream river obstruction was observed along the river course which according to Schmutz and Moog (2018), is among the most damaging human activities in river basins, deeply modifying the physiography of watersheds by altering downstream flow and sediment transport. Gichuki, (2002) revealed that high levels of water abstraction in the upper reaches of Ewaso Ngiro have been blamed for decreasing water availability in the lower reaches. Matunda (2015) in his study critiquing the legislative framework governing riparian areas in Kenya, argues that the nation lacks a cohesive legislative framework to safeguard and direct the management of riparian zones. He goes on to say that the law is dispersed throughout many bills and is not well-established in terms of approval or enforcement mechanisms.

5.4 Effects of riparian degradation

The effects of riparian degradation are cyclic in that the causal factors of degradation are the same victims when the effects of riparian degradation set in. An example revealed in the study is crop farming which was also a cause. The effects of degradation in the area were found to be statistically significant with the majority of the respondents claiming to have been affected. The main effect of crop farming was a reduced supply of water for irrigation. Key informants also emphasized the same reporting that degradation has led to low yields and insufficient water for irrigation. Livestock keeping has also been significantly affected mainly because they depend on water from the river for watering their animals and fodder from the riverside during dry seasons. Reduced fodder sources were identified to be the most significant effect that degradation had on livestock keeping. These challenges ultimately result in to rise in the cost of living and poor nutrition in the area. A study by Onuoha (2008) showed that the impact of the degradation of Lake Chad and its natural resources was felt by the Lake Chad basin population who depended on the lake for their means of livelihood.

The study found that riparian degradation in Kaiti River has significantly affected water for domestic use with the leading effects being reduced availability of clean water for washing and cooking. This led to increased waterborne diseases and increased cost of water for drinking. The interaction with key informants and FGDs revealed that degradation had led to the unavailability of both clean and enough water for domestic use. Kieti et al. (2016) reported the decline of ground water and the drying of rivers as some of the factors predisposing farmers to adopt inappropriate farming methods and unsustainable livelihood strategies which compromise the watershed's environmental integrity.

The majority of the respondents agreed that degradation has also significantly affected the riparian biodiversity and socio-economic value. The findings revealed that reduced riparian vegetation was the main degradation effect on biodiversity. The interaction with key informants pointed to a compromised riparian aesthetic value because of degradation. Wildlife in the riparian zones including birds and fish varieties had also been significantly affected. According to Owino (2008), tropical birds are generally more affected by habitat loss than temperate birds, and many forest-dwelling birds are affected by deforestation, loss and degradation.

The key informants and FGDs added that degradation harmed both the quantity and quality of the biodiversity in the riparian zones and on the economy due to the high cost towards maintenance of infrastructure, loss of land due to widening riverbanks, land value decrease and increase in riparian land social conflicts. Latent conflicts are typically dormant until they are reawakened by scarcity and/or inequitable allocation of the scarce resource, usually during seasons of drought, according to research by Gichuki in 2002. Conflicts are further exacerbated by social inequality, economic marginalization, and poverty. Water users' associations, according to Kiteme & Gikonyo (2002), are a useful tool for resolving disputes relating to the usage of water.

5.5 Degradation indicators

According to the study, the disappearance of bird and plant species, reduced water flow and disappearance of fish species could be used as general indicators of riparian degradation happening in the region. The same was emphasized by key informants and focus groups who added reduced population of animals like birds, increased speed of water, water becoming dirtier, widening of rivers; sand composition; exposed rocks, drying aquifers, drying river wells, reduced income levels from riparian land investments and land-based conflicts as other indicators of riparian degradation. Wichert et. al., 1998, identifies fish community structures as a reliable measure of riparian degradation and rehabilitation.

Macfarlane et. al., 2017, propose riparian vegetation as a reliable indicator for riparian degradation. This is supported by the fact that riparian ecosystems support unique vegetation communities and high biodiversity relative to terrestrial landscapes. A botanical study of the Kaiti River floor and the riparian zone at five points along the river transect confirmed the argument by revealing 10 riparian degradation and 5 high water table indicator plant species. The 10 degradation indicator species included *Euphorbia schefflera*, *Balanites aegyptiaca, Acacia tortilis*, *Lantana camara*, *Croton dichogamus*, *Ipomoea kituiensis*, *Nicotiana glauca*, *Combretum mole*, *Combretum collinum* and *Schkuhria pinnata.* According to Tuvshintogtokh (2014), degradation indicator plants are grazing-tolerant plants, unpalatable and badly palatable livestock plants, or stress-tolerant plants and ruderals so they can remain after hard grazing and damage to the ecosystem. All ten species qualify for this description. Chothani et. al., (2011) *describe Balanites aegyptiaca* also known as the "Desert Date", as a thorny tree or shrub up to 10 meters high, commonly found in dry regions of Africa and South Asia thus the availability of the species in riparian zones would indicate heightened degradation.

Typically, disturbed or degraded environments are where you can find *Ipomoea kituiensis*. The plant demonstrates the majority of traits typical of invasive species, including the ability to expand quickly, disseminate, and reproduce widely or by raising fewer offspring but very effectively. (Bosco et. al., 2015). Kimothi et al., (2010), state that *Lantana camara* is one of the most dangerous invasive plant species that has invaded significant regions of forest in the Himalayan foothills, it grows extensively in damaged and scant woods. The species has equally invaded the Kaiti River riparian zone replacing riparian vegetation way up to the river banks. A riparian plant diversity study by Schmitt, Kisangau, & Matheka, (2019) in Kitui County found that *Lantana camara* dominated the invasive thickets on the riparian zones. Kato-Noguchi, H., & Kurniadie, D. (2021) Suggest that the allelopathic property of *L. camara* may support its invasive potential and formation of dense monospecies stands. Jean et al., (2021), in their study of the reforestation of Miombo woodlands, propose *Combretum collinum* as a suitable species for reforestation of degraded forests citing its ability to withstand degradation forces. Most of these plants were found growing on the riverbanks and on the river floor indicating a high level of degradation. *Lantana camara* was found profusely invading whole portions of riverbanks, especially on sections rarely accessible by humans.

High water table indicator species were sought to identify areas of past healthy riparian vegetation populations that are declining due to degradation. According to Scott et al., 2000, as floodplains and channels are decoupled, riparian plant performance declines, reducing many riparian species' competitive abilities. High water table indicators are plants that have undergone morphoanatomical adaptations because of restrictions imposed by lengthy periods of waterlogging or total submergence, in addition to the wide range of methods used by species to cope with flooding (Marina & Damelis, 2020). Some of these species identified at the Kaiti River riparian zone are *Acacia elatior, Kanahia longiflora*, *Ficus sycomorus, Acacia polyacantha and Phragmites Mauritius.* Indicators of the high-water table like *Phragmites Mauritius* were themselves degraded due to overgrazing indicating a risk in the future ability of the river resource to provide an alternative source of fodder during dry spells. *Acacia polyacantha* is common in Africa, but at low density, often near water or in areas with a high water table; It stands out small and is located on stands out on meadows next to riverside woodlots. (Sharam et al. 2009). Erhirhie et al. (2018) describe *Ficus sycomorus* as a widespread savannah tree which thrives in high-water table areas. Ihwagi et al., (2010) in their study at Samburu and Buffalo Springs, found out that *Acacia elatior,* was the most abundant tree species in the riverine zone, accounting for 68% of woody plants.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study revealed that the Kaiti River has experienced degradation which has significantly altered the river resource and affected the adjacent communities in diverse ways. The period 1990s was when degradation was accelerated with periodical surges in degradation mainly fueled by climate change factors. Eroded riverbanks and vegetation change are evidence of the prevalence of degradation in the riparian zone as well as exposed rocks and dry riverbeds.

Awareness of riparian conservation was found to be a significant factor influencing the degradation of the Kaiti River watershed. The communities adjacent to Kaiti River though having low education and income levels, had fair knowledge, and understanding of riparian conservation matters with the majority having participated in training on conservation practices. CSOs including NGOs, CBOs, Faith-based organizations, and networks were found to be taking a leading role in riparian conservation awareness creation. The study found that registration into WRUAs and member training would significantly improve riparian conservation awareness which would in turn have the effect of reducing riparian degradation.

Farming of Mango and citrus fruits was the main agricultural activity and was well integrated with agroforestry and the use of organic manure and cover crops. Specific farming practices were however found to significantly contribute to the degradation of the Kaiti River riparian zone; these included farming along the riparian zone and on steep slopes coupled with settlement on the river catchment. Livestock keeping was mainly practiced through tethering and free grazing which coupled with insufficient pasture round the year for most farmers, led to overgrazing in the riparian zone, especially during dry spells leading to degradation of the riparian vegetation. Commercial sand harvesting was found to be a significant threat to riparian degradation though it had been greatly controlled along the riparian zone in the last decade. Poverty, poor riparian resource governance, climate change, land use change and upstream river obstruction were other highlighted causes of riparian degradation.

The study therefore concluded that lack of riparian conservation awareness, poor farming practices along the riparian zone, overgrazing in the riparian zone and uncontrolled commercial sand harvesting were the main causes of degradation in the Kaiti River riparian ecosystem. Other catalysing factors to degradation were found to be climate change, poverty, and poor natural resource governance.

The study revealed that the Kaiti River riparian degradation was considerably harming the neighbouring population, with a decline in the supply and quality of water for irrigation and reduced productivity of river-irrigated farms. Watering points for cattle had also been reduced and fodder availability for cattle especially during drought periods reduced translating to a high cost of cattle farming. Clean drinking water that could cheaply be obtained from the riverside was not available and whatever was available was no longer safe. Clean water for washing and cooking had also become scarce from the river. The river's biodiversity and aesthetic value had been affected evidenced by changed and reduced vegetation cover, reduced variety of birds, dried water pools as well as exposed rocks and riverbanks. Wild animals and birds that took advantage of the riverine forest patches had greatly reduced as the vegetation disappeared. Fish availability in the river hasd also been reduced greatly. Other effects experienced in the riparian zone were reduced income for the communities dependent on the river resource and increased human conflicts. Among the effects mentioned, the most significant were the effects on crop farming, livestock keeping, water availability for domestic use and river biodiversity.

The three main indicators of Kaiti River riparian degradation were vegetation change, disappearance of bird and fish species and reduced water flow. The vegetation change as an indicator of riparian degradation was supported by the presence of the ten reliable degradation plant indicator species listed in Table 4.21. And five high water table plant indicators species listed in table 4.22.

6.2 Recommendations

The study makes the following recommendations for consideration in the management of the Kati riparian zone and other riparian ecosystems in the semi-arid regions of Kenya, as well as in future studies.

1. There is a need for communities adjacent to the Kaiti River and similar watersheds to be empowered to raise their level of education and income which would in turn reduce dependence on natural resources for livelihoods. More awareness of income-generating activities is needed. The community should also be educated on family planning to reduce population pressure on land which in turn hurts the riparian ecosystem.
2. Existing WRUAs should be strengthened, increase their visibility and encourage more membership. The youth should also be encouraged to join WRUAs through sensitization as well as making the WRUAs youth-friendly.
3. Effective, consistent and community-based monitoring of riparian zones should be encouraged with community-led organizations leading in the implementation of restoration and conservation while still monitoring the status of the riparian areas.
4. Both national and County governments should finance restoration programs, training and awareness creation on riparian conservation, policing and enforcement. Non-governmental organizations should similarly be engaged in awareness creation, efficient and effective technology transfer for sustainable utilization of resources and participate in the financing of conservation activities. The policies governing rivers and the secured buffer size should be made known to the community and enforced appropriately, especially around crop farming, grazing and tree cutting.
5. The community living along the Kaiti River riparian ecosystem should be trained more on best practices in farming and why they should care about the riparian ecosystem. Trainings targeting proper use of fertilizer and pesticides, affordable soil, and water conservation technologies as well as agroforestry integration in crop farming would be beneficial. Sustainable livestock keeping methods should also be promoted especially zero grazing for cattle. The community should be sensitized

on climate change adaptation technologies to help them bear with adverse effects of climate change.

6. Future studies should consider quantifying further the levels of degradation and alien species invasion in the semi-arid riparian zones of Kenya.

REFERENCES

Abuya, B. A., Ciera, J., & Kimani-Murage, E. (2012). *Effect of mother's education on child's nutritional status in the slums of Nairobi*. BMC Pediatrics, 12(1), 1-10.

Ashraf, M. A., Maah, M. J., Yusoff, I., Wajid, A., & Mahmood, K. (2011). Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. *Scientific Research and Essays*, *6*(6), 1216-1231.

Barker, T., Hatton, K., O'Connor, M., Connor, L., & Moss, B. (2008). *Effects of nitrate load on submerged plant biomass and species richness: results of a mesocosm experiment.* Fundamental and Applied Limnology, 173(2), 89.

Bezabih, B., & Mosissa, T. (2017). Review on distribution, importance, threats and consequences of wetland degradation in Ethiopia.

Boisjolie, B., Flitcroft, R., & McCoy, A. (2020). Restoration of Riparian Habitats. *Encyclopedia of the World's Biomes*, 430-437.

Bosco, K. K., John, M. K., Everlyne, K. C., Robert, N., Halima, N., & William, M. N. (2015). Key informant perceptions on the invasive ipomoea plant species in Kajiado County, South Eastern Kenya. *Agriculture, Forestry and Fisheries*, *4*(4), 195-199.

Briggs, M. K. (1995, April). *Evaluating degraded riparian ecosystems to determine the potential effectiveness of revegetation*. In Proceedings: Wildland shrub and arid land restoration symposium (pp. 63-67).

Brito, J. G., Roque, F. O., Martins, R. T., Nessimian, J. L., Oliveira, V. C., Hughes, R. M., ... & Hamada, N. (2020). *Small forest losses degrade stream macroinvertebrate assemblages in the eastern Brazilian Amazon.* Biological Conservation, 241, 108263.

Capon, S. J., Chambers, L. E., Mac Nally, R., Naiman, R. J., Davies, P., Marshall, N., ... & Williams, S. E. (2013). Riparian ecosystems in the 21st century: hotspots for climate change adaptation? Ecosystems, 16, 359-381.

Catford, J. A., Naiman, R. J., Chambers, L. E., Roberts, J., Douglas, M., & Davies, P. (2013). Predicting novel riparian ecosystems in a changing climate. *Ecosystems*, *16*(3), 382-400.

Chen, F., Lu, S., Hu, X., He, Q., Feng, C., Xu, Q., ... & Guo, H. (2019). *Multi-dimensional habitat vegetation restoration mode for lake riparian zone, Taihu, China*. Ecological Engineering, 134, 56-64.

Chen, J., Wang, P., Wang, C., Wang, X., Miao, L., Liu, S., & Yuan, Q. (2019). *Dam construction alters the function and community composition of diazotrophs in riparian soils across an environmental gradient*. Soil Biology and Biochemistry, 132, 14-23.

Chothani D.L., & Vaghasiya H.U., (2011). A review on *Balanites aegyptiaca*.Del (desert date): phytochemical constituents, traditional uses, and pharmacological activity. Pharmacognosy Reviews; 5(9):55-62. DOI: 10.4103/0973-7847.79100.

Clary, W. P., & Leininger, W. C. (2000). Stubble height as a tool for the management of riparian areas. *Rangeland Ecology & Management/Journal of Range Management Archives*, *53*(6), 562-573.

Connolly, N. M., Pearson, R. G., Loong, D., Maughan, M., & Brodie, J. (2015). Water quality variation along streams with similar agricultural development but contrasting riparian vegetation. *Agriculture, ecosystems & environment*, *213*, 11-20.

Dada P. O. O., Musa J. J., Adewumi J. K., & Ola I. A. (2019). *cattle treading effects on soil physical and hydraulic properties in Abeokuta, southwestern Nigeria*. Minna: Nigeria

Ding S., Zhang Y., Liu, B., Kong W., & Meng W. (2013). Effects of riparian land use on water quality and fish communities in the headwater stream of the Taizi River in China. *Frontiers of Environmental Science & Engineering*, *7*(5), 699-708.

Dogra B. (1986). The Indian experience with large dams. The Social and Environmental Impact of Large Dams. Vol. 2, Case Studies. Cornwall (UK): Wadebridge Ecological Centre, Pages 201–218 in Goldsmith E, Hildyard N, eds.

Duveskog[1], D., Mburu, C., & Critchley, W. (2003). *Harnessing indigenous knowledge and innovation in Farmer Field Schools. In Farmer field schools: Emerging issues and challenges. International Learning Workshop on Farmer Field Schools (FFS).* Yogyakarta (Indonesia). 21-25 Oct 2002. (p. 197). International Potato Center.

English M.C., Hill R.B., Stone M.A., & Ormson R. (1997). Geomorphological and botanical changes on the Outer Slave River delta, NWT, before and after the impoundment of the Peace River. Hydrological Processes 11:1707–1724.

Erhirhie, E. O., Ilodigwe, E. E., & Ihekwereme, C. P. (2018). *Ficus Sycomorus L (Moraceae): A review of its Phytopharmacology and toxicity profile*. Discovery Phytomedicine, 5(4), 64-71.

Erhirhie, E. O., Ilodigwe, E. E., & Ihekwereme, C. P. (2018). Ficus Sycomorus L (Moraceae): A review of its Phytopharmacology and toxicity profile. *Discovery Phytomedicine*, *5*(4), 64-71.

Gashaw, T., Terefe, H., Soromessa, T., Ahmed, S., & Megersa, T. (2015). Riparian areas rehabilitation and restoration: An overview. *Point J Agric Biotechnol Res*, *1*(2), 055-063.

Gichuki, F. N. (2002). Water scarcity and conflicts: A case study of the Upper Ewaso Ng'iro North Basin. *The Changing Face of Irrigation in Kenya: Opportunities for Anticipating Change in Eastern and Southern Africa*, 113-134.

Gonzalez del Tanago, M., & Garcia de Jalon, D. (2011). Riparian Quality Index (RQI): *A methodology for characterising and assessing the environmental conditions of riparian zones*. *Limnetica*, *30*(2), 0235-254.

Government of Kenya (GOK). (2013) *Makueni's first county integrated development plan* 2013-2017. Government Printer, Nairobi, Kenya. pp: 2-36.

Haipeng Wu, Jin Chen, Jijun Xu, Guangming Zeng, Lianhai Sang, Qiang Liu, Zhengjie Yin, Juan Dai, Dacong Yin, Jie Liang, Shujing Ye, *Effects of dam construction on biodiversity*: A review, Journal of Cleaner Production, 10.1016/j.jclepro.2019.03.001, (2019).

Hodge, R. W., & Treiman, D. J. (1968). Social participation and social status. *American Sociological Review*, 722-740.

Ihwagi, F. W., Vollrath, F., Chira, R. M., Douglas-Hamilton, I., & Kironchi, G. (2010). The impact of elephants, Loxodonta africana, on woody vegetation through selective debarking in Samburu and Buffalo Springs National Reserves, Kenya. *African Journal of Ecology*, *48*(1), 87-95.

Jacoba Salinas M., Gabriel Blanca & Ana T. Romero (2000). *Evaluating riparian vegetation in Semi-Arid Mediterranean watercourses in the south-eastern Iberian Peninsula*. Environmental Conservation, pp 24-35.

Jansen, H. (2010). The logic of qualitative survey research and its position in the field of social research methods. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 11, No. 2).

Jean Marc Kaumbu, K., Mubemba Mulambi Michel, M., Emery Lenge Mukonzo, K., Mylor, N. S., Honoré, T., Nkombe Alphonse, K., & Dey, D. C. (2021). Early Selection of Tree Species for Regeneration in Degraded Woodland of Southeastern Congo Basin. *Forests (19994907), 12*(2).

Julia Glenday (2018) "*Carbon Storage and Carbon Emission Offset Potential in an African Riverine Forest, the Lower Tana River Forests, Kenya*," Journal of East African Natural History 97(2), 207-223. https://doi.org/10.2982/0012-8317-97.2.207

Julius M., et. al., (2013). *Kaiti watershed Baseline Survey report*: Nairobi; Kenya. ERMIS Africa.

Kafumbata, D., Jamu, D., & Chiotha, S. (2014). Riparian ecosystem resilience and livelihood strategies under test: lessons from Lake Chilwa in Malawi and other lakes in Africa. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639), 20130052.

Kamar, M. J. (2001). Role of Kenyan women's groups in community-based soil and water conservation: *A case study. In 10th International Soil Conservation Organization Meeting, West Lafayette, IN.*

Kanga, E. M., Ogutu, J. O., Piepho, H. P., & Olff, H. (2013). *Hippopotamus and livestock grazing: influences on riparian vegetation and facilitation of other herbivores in the Mara Region of Kenya.* Landscape and Ecological Engineering, 9, 47-58.

Kapp (2011), *A baseline survey on the marketing of sorghum*; Kenya www.kapp.go.ke

Kato-Noguchi, H., & Kurniadie, D. (2021). Allelopathy of Lantana camara as an invasive plant. Plants, 10(5), 1028.

Kieti R.N., Kauti M.K. & Kisangau D.P., (2016). Biological Conditions and Land Use Methods Contributing to Watershed Degradation in Makueni County, Kenya. Journal of Ecosystem & Ecography. 6:4.

Kimothi, M. M., Anitha, D., Vasistha, H. B., Soni, P., & Chandola, S. K. (2010). *Remote sensing to map the invasive weed, Lantana camara in forests*. *Trop Ecol*, *51*(1), 67-74.

Kiteme, B. P., & Gikonyo, J. (2002). Preventing and resolving water use conflicts in the Mount Kenya highland–lowland system through water users' associations. *Mountain research and development*, *22*(4), 332-337.

Levy, P. S., & Lemeshow, S. (2013). *Sampling of populations: methods and applications*. John Wiley & Sons.

Ludwig, J. A., Wilcox, B. P., Breshears, D. D., Tongway, D. J., & Imeson, A. C. (2005). Vegetation patches and runoff–erosion as interacting ecohydrological processes in Semi-Arid landscapes. Ecology, 86(2), 288-297.

Macfarlane, W. W., Gilbert, J. T., Jensen, M. L., Gilbert, J. D., Hough-Snee, N., McHugh, P. A., ... & Bennett, S. N. (2017). *Riparian vegetation as an indicator of riparian condition*: Detecting departures from historic condition across the North American West. Journal of Environmental Management, 202, 447-460.

Magnani, R. (2015). Sampling guide. Washington: Food and Nutrition Technical Assistance Project; 1997.

Malombe I., Kimeu J., Matheka K.W. & Chesire C., Musila S., Mutati A & Zuhura A. (2012). *An assessment of the ecosystem, socio-economic status and identification of local institutions dealing with natural resources management and governance within the Kaiti watershed:* National Museums of Kenya, Nairobi.

Maluki, J. M., Kimiti, J. M., Nguluu, S. N., & Musyoki, J. K. (2016). *Adoption levels of agroforestry tree types and practices by smallholders in the semi-arid areas of Kenya*: A case of Makueni County.

Marina García & Damelis Jáuregui (2020). Morphoanatomical Characteristics in Riparian Vegetation and Its Adaptative Value, River Basin Management - Sustainability Issues and Planning Strategies, José Simão Antunes Do Carmo, IntechOpen, DOI: 10.5772/intechopen.94933.

Matano, A. S., Kanangire, C. K., Anyona, D. N., Abuom, P. O., Gelder, F. B., Dida, G. O., & Ofulla, A. V. (2015). Effects of land use change on land degradation reflected by soil properties along Mara River, Kenya and Tanzania. *Open Journal of Soil Science*, *5*(01), 20.

Matunda, J. M. (2015). Sustainable management of riparian areas in Kenya: a critique of the inadequacy of the legislative framework governing the protection of sustainable management of riparian zones in Kenya (Doctoral dissertation, University of Nairobi).

Mee L.D., (1992). The Black Sea in crisis: *A need for concerted international action*. Ambio 4: 278–286.

Miserendino, M. L., Casaux, R., Archangelsky, M., Di Prinzio, C. Y., Brand, C., & Kutschker, A. M. (2011). Assessing land-use effects on water quality, in-stream habitat, riparian ecosystems and biodiversity in Patagonian northwest streams. *Science of the total environment*, *409*(3), 612-624.

Mugachia, J. C., Kanja, L., & Gitau, F. (1992). Organochlorine pesticide residues in fish from Lake Naivasha and Tana River, Kenya. *Bulletin of environmental contamination and toxicology*, *49*(2), 207-210.

Mutua, U. M., Kisangau, D., & Musimba, N. (2019). *Assessing the impact of farming systems and land use change on dryland plant biodiversity*: a case study of Mwala and Yatta sub-counties in Machakos County, Kenya. *International Journal of Environment, Agriculture and Biotechnology*, *4*(5).

Mwei, O. J. (2016). *Factors Influencing Youth Participation In The Implementation Of Community Development Projects: A Case Of Konoin Sub-County, Bomet County, Kenya* (Doctoral dissertation, University Of Nairobi).

Mworia, L. M., Sande, A., & Kiboro, C. (2019). Water Resource Users Associations Catchment Protection Strategies on Promotion of Sustainable Water Projects in Tana Catchment Area, Kenya. Journal of African Interdisciplinary Studies, 3(7), 134-146.

Ndeti, L. N, (2013). *Factors influencing the performance of water resource users' Associations on conservation of water catchment areas in Kibwezi, Kenya* (Doctoral dissertation, University of Nairobi,).

Nyang, M.N, Webo, C. & R.L Roothaert, (2010). *The Power of Farmer's Organisations in Smallholder Agriculture in East Africa Working Papers*. A review of 5 project initiatives of the Maendeleo Agricultural Technology Fund. In FARM-Africa Working Paper, London, UK, FARM-Africa. 2010: 1-44.

Nzau, J. M., Rogers, R., Shauri, H. S., Rieckmann, M., & Habel, J. C. (2018). Smallholder perceptions and communication gaps shape East African riparian ecosystems. *Biodiversity and Conservation*, *27*(14), 3745-3757.

Odada E. O., Olago, D. O., Kulindwa, K., Ntiba, M., & Wandiga, S., (2004). Mitigation of Environmental Problems in Lake Victoria, East Africa: Causal Chain and Policy Options Analyses. Ambio Vol. 33 No. 1–2.

Olokeogun, O. S., & Kumar, M. (2020). *An indicator-based approach for assessing the vulnerability of riparian ecosystems under the influence of urbanization in the Indian Himalayan city*, Dehradun. *Ecological Indicators*, *119*, 106796.

Onuoha, F. C. (2008). Environmental degradation, livelihood and conflicts: A focus on the implications of the diminishing water resources of Lake Chad for north-eastern Nigeria. *African journal on conflict resolution*, *8*(2), 35-61.

Owino, A. O., Amutete, G., Mulwa, R. K., & Oyugi, J. O. (2008). Forest patch structures and bird species composition of a lowland riverine coastal forest in Kenya. *Tropical Conservation Science*, *1*(3), 242-264.

Perry, L. G., Andersen, D. C., Reynolds, L. V., Nelson, S. M., & Shafroth, P. B. (2012). Vulnerability of riparian ecosystems to elevated CO2 and climate change in arid and semiarid western North America. *Global Change Biology*, *18*(3), 821-842.

Richardson, D. M., Holmes, P. M., Esler, K. J., Galatowitsch, S. M., Stromberg, J. C., Kirkman, S. P., ... & Hobbs, R. J. (2007). *Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Diversity and Distributions*, 13(1), 126-139.

Robertson, A. I., & Rowling, R. W. (2000). Effects of livestock on riparian zone vegetation in an Australian dryland river. *Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management*, *16*(5), 527-541.

Samantha J. Capon, *et. al.* (2013): Riparian Ecosystems in the 21st Century: Hotspots for Climate Change Adaptation? Vol. 16, No. 3 (April 2013), pp. 359-381 (article consists of 23 pages)

Sá-Oliveira, J. C., Hawes, J. E., Isaac-Nahum, V. J., & Peres, C. A. (2015). Upstream and downstream responses of fish assemblages to an eastern Amazonian hydroelectric dam. *Freshwater Biology*, *60*(10), 2037-2050.

Saris, W. E., & Gallhofer, I. N. (2014). *Design, evaluation, and analysis of questionnaires for survey research*. John Wiley & Sons.

Schmitt, C. B., Kisangau, D., & Matheka, K. W. (2019). *Tree diversity in a human-modified riparian forest landscape in semi-arid Kenya*. Forest Ecology and Management, 433, 645-655.

Schmutz, S., & Moog, O. (2018). Dams: ecological impacts and management. In *Riverine ecosystem management* (pp. 111-127). Springer, Cham.

Scott, R. L., Shuttleworth, W. J., Goodrich, D. C., & Maddock III, T. (2000). The water use of two dominant vegetation communities in a semiarid riparian ecosystem. Agricultural and Forest Meteorology, 105(1-3), 241-256.

Sharam, G. J., Sinclair, A. R. E., Turkington, R., & Jacob, A. L. (2009). The savanna tree Acacia polyacantha facilitates the establishment of riparian forests in Serengeti National Park, Tanzania. *Journal of Tropical Ecology*, 31-40.

Singh, R., Tiwari, A. K., & Singh, G. S. (2021). Managing riparian zones for river health improvement: an integrated approach. Landscape and ecological engineering, 17, 195-223.

Suring, L. H. (2020). Freshwater: Oasis of Life—An Overview.

Tererai, F., Gaertner, M., Jacobs, S. M., & Richardson, D. M. (2013). *Eucalyptus invasions in riparian forests*: *effects on native vegetation community diversity*, *stand structure and composition*. Forest Ecology and Management, *297*, 84-93.

UNDP (Ed.). (2015). Human Development Report 1994. New York: USA. http://hdr.undp.org/sites/default/files/2015_human_development_report_0.pdf

Wanyama, J., Masinde, G., & Obare A., (2013). Factors Influencing Adoption of Tissue Culture; *proceedings of the 4th International Conference of AAAE held at Diar Lemdina Hotel* – Yasmine Hammamet, Tunisia on 22nd – 25th September, 2013

Wichert, G. A., & Rapport, D. J. (1998). *Fish community structure as a measure of degradation and rehabilitation of riparian systems in an agricultural drainage basin*. Environmental Management, 22, 425-443.

Woolsey, T. D. (1956). Sampling methods for a small household survey (No. 480). US Department of Health, Education, and Welfare, Public Health Service.

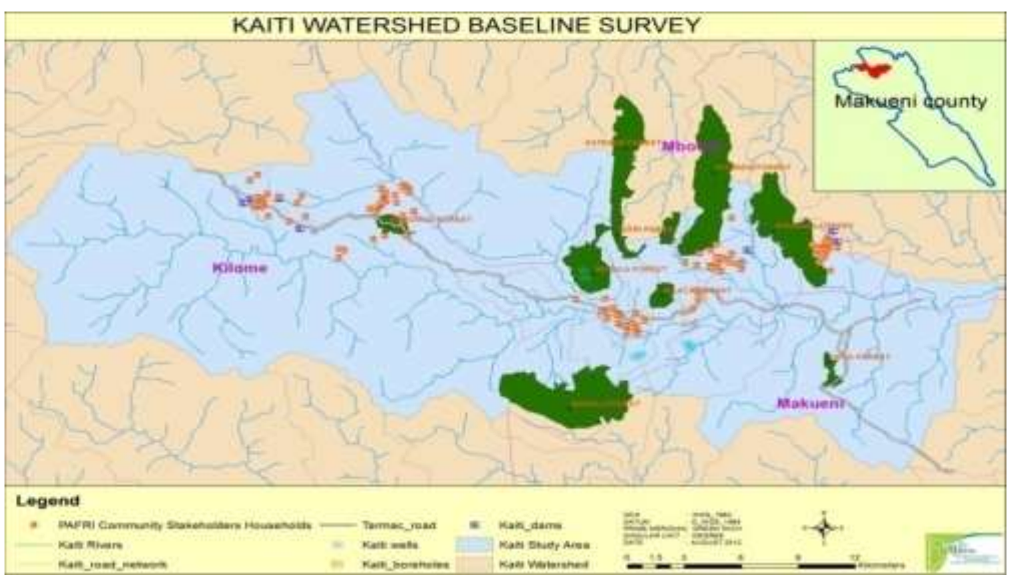
World Bank. 2014. *The World Bank Annual Report 2014: Main report (English)*. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/111781468170952958/Main-report

Zaimes, G. N., Gounaridis, D., & Symenonakis, E. (2019). Assessing the impact of dams on riparian and deltaic vegetation using remotely-sensed vegetation indices and Random Forests modelling. *Ecological Indicators*, *103*, 630-641.

APPENDICES

Appendix 1: Maps

A map showing the Kaiti watershed. Source: Baseline survey Preserve Africa Initiative (PAFRI) 2013



The network of streams in the Kaiti watershed. Source: Baseline survey Preserve Africa Initiative (PAFRI) 2013

Appendix ii: Questionnaires

2.1 Household questionnaire

SOUTH EASTERN KENYA UNIVERSITY (SEKU)

An Investigation of Degradation Level and Its Effects on The Riparian Ecosystems of Eastern Semi-Arid Region of Kenya; A Case Study of Kaiti River, Makueni County.

All data gathered from this survey is confidential and will be used solely for academic purposes.

Informed Consent Form

Research is being undertaken to assess and document the causes, effects and key indicator species of degradation in the riparian ecosystems of the Semi-Arid regions of Kenya with Kaiti River being the case of study. *The research is being carried out by* an environmental management master's student of South Eastern Kenya University namely Charles Kisima Kimani Reg. No. **I501/WTE/20248/2012,** ID.NO. **25872270**.

<u>RESIDENTS CATEGORY</u>

QUESTIONNAIRE SERIAL NO.		
GPS POINT /QUADRANT		

<u>SECTION A: HOUSEHOLD IDENTIFICATION</u>

DATE OF INTERVIEW	Day:	Month:	Year:
NAME AND GENDER OF RESPONDENT	Name:		Gender:
NAME OF HOUSEHOLD HEAD/RELATION WITH HOUSEHOLD HEAD	Name:	Relation:	Gender
EXTENDED FAMILY NAME (CLAN NAME)	Name		
VILLAGE NAME/ SUB LOCATION	Village	Sub-location	

SECTION B: RESPODENT'S GENERAL INFORMATION

B1. Age of Respondent___________________________

B2. Level of education_________________________

B3. Marital Status 1. Single ☐ 2. Married ☐

B4. Household size _________________________

B5: Occupation of household head

a. Agriculture
b. Forestry
c. Business Man
d. Employed (salaried)
e. Other; Specify ________________________

B6: What is your total land acreage _____________________

B7: How have you segregated your land in terms of land use:-

#	**Land use**	**Acreage**
1.	Crop farming	
2.	Livestock keeping	
3.	Forestry/plantation	
4.	Others (specify) _________________	
	TOTAL	

B8: Income level per annum Below 100,000 ☐ 100,000 – 300,000 ☐ 300,000 – 700,000 ☐ Above 700,000☐

B9: What is the approximate distance of the Kaiti river from your home?

Less than 1km ☐ 1-3 km ☐ 3-5 km ☐ above 5km ☐

SECTION C: EVIDENCE AND EXTENT OF KAITI RIPARIAN DEGRADATION:

(Rate the following three statements according to your observations in the Kaiti river)

C1. There has been much degradation happening in the Kaiti riparian ecosystem.

1. Strongly agree 2. Agree 3. Neither agree nor disagree 4. Disagree 5. Strongly disagree.

C2. The degradation happening in the Kaiti riparian ecosystem has greatly affected the river resources.

1. Strongly agree 2. Agree 3. Neither agree nor disagree 4. Disagree 5. Strongly disagree.

C3: Which period would you say degradation became significant?

1970s ☐ 1980s ☐ 1990s ☐ 2000s ☐ 2010s ☐ Don't know ☐

C4. What are some of the evidences of degradation which you can point out in the Kaiti riparian zone?

1. Eroded river banks
2. Dry river beds
3. Exposed rocks
4. Vegetation loss within the riparian zone.
5. Vanishing of wildlife once noticed in the riparian zone
6. Dried wells
7. Others (specify)_______________________________

SECTION D: CAUSES OF RIPARIAN DEGRADATION

Riparian conservation awareness

D1: Do you belong to a Water Resource User's association? ☐YES ☐ NO

D2: Have you ever participated in any of Kaiti river's community conservation activities?

☐YES ☐ NO

D3. How would you rate your understanding of riparian ecosystem conservation?

1. Excellent 2. Good 3. Fair 4. Poor 5. Very poor.

D4. Have you received any training on conservation practices? ☐YES ☐ NO

D5. If yes, What are they?

1. Soil erosion control (gabions, cutoffs)
2. Water harvesting (sand dams, water pans, cutoffs).
3. Conservation of water sources
4. Livestock management
5. Sand harvesting and control
6. Agro forestry systems
7. Tree planting
8. Land use management
9. Conservation agriculture (contour farming, farming on steep slopes, cover crops, rotation)
10. Soil fertility management (use of manure and fertilizers)
11. Agrochemical usage
12. Others (specify)____

D6. Do you practice any of this training knowledge? ☐YES ☐NO

D7. If yes, what are they?

1. Soil erosion control (gabions, cutoffs)
2. Water harvesting (sand dams, water pans, cutoffs).
3. Conservation of water sources
4. Livestock management
5. Sand harvesting and control
6. Agro forestry systems
7. Tree planting
8. Land use management
9. Conservation agriculture (contour farming, farming on steep slopes, cover crops, rotation)
10. Soil fertility management (use of manure and fertilizers)
11. Agrochemical usage
12. Others (specify)____

D8: To what extend do you practice the practices you have specified above?

1. Intensively 2. Fairly 3. Slightly

D9: What are the limiting factors in applying the knowledge trained?

1. Difficult technologies to understand
2. Poor training methods
3. Political interference
4. Weak policies
5. Lack of empowerment to implement the knowledge
6. Ignorance
7. Others (specify)____

D10. Who have been responsible for most of the trainings received?

1. The government
2. CSOs (NGO, Churches, CBO, NETWORKS e.t.c)
3. The private sector (business partners e.g.agrochemical industries)
4. Others (specify)____

<u>Crop farming</u>

D11. Which crops do you cultivate in your farm?

1. Cereals (maize, beans, peas, green grams)
2. Fruits (Mangoes, Avocado, Oranges, pawpaw)
3. Root Tubers (Potatoes, Cassava)
4. Others (specify)____

D12: Do you have an established agro forestry system in your farm?

☐ YES ☐ NO

D13: Which agro-forestry system do you use in your farm?

1. Wind breaks
2. Intercropping
3. Boundary system
4. Alley cropping
5. Planting on terraces
6. Other (Specify)_______________

D14: which soil fertility management do you use?

1. Inorganic fertilizers
2. Organic manure
3. Cover crops
4. Nitrogen fixing trees
5. None
6. Other (specify)________________________________

D15: What do you think are some of the farming practices contributing to Kaiti river riparian degradation?

1. Farming on steep slopes
2. Settlement in river catchments
3. Farming along the riparian zone.
4. Others (specify)______________________________

Livestock Management

D16: How many livestock do you keep per type?

Livestock Type	**Number**
Cows	
Goats	
Sheep	
Donkeys	
Others (specify) ______________	
TOTAL	

D17. Which method do you use for keeping the livestock?

1. Zero grazing
2. Tethering
3. Free grazing in the field
4. Others (specify)________________________

D18. Do you have enough pasture to graze your cattle throughout the year?

YES ☐ NO ☐

D19: If NO, where do you get the additional fodder?

1. Buying from neighbours
2. Buying from rangelands
3. Buying from the agro shops
4. Grazing on the riverside
5. Others (Specify) ____

D20. If grazing is done on the riverside, how frequent?

1. Through out
2. During the dry spells
3. Seldomly
4. Others (Specify)_____________________

Deforestation

D21: Have you noticed tree/ vegetation cover changes in your area?

YES ☐ NO ☐

D22: If yes, what are the observable changes?

1. Reduced vegetation cover
2. Increased vegetation cover
3. No change in vegetation cover

D23: If C22:1 is true, what has been the main cause?

1. Deforestation for construction
2. Deforestation for wood fuel
3. Deforestation for charcoal burning
4. Deforestation for crop farming.
5. Climate change
6. Others (specify)____

Sand Harvesting

D24: Is commercial sand harvesting practiced in this section of Kaiti river near you?

YES ☐ NO ☐

D25: If yes, how has it affected the riparian ecosystem?

Greatly degrading ☐ slightly degrading ☐ No effect ☐

D26: What are the other main causes of degradation in the Kaiti riparian ecosystem?

1. Poor natural resource management/ governance
2. Poverty
3. Infrastructure
4. Climate change
5. Others (Specify)________________________________

SECTION E: EFFECTS OF RIPARIAN DEGRADATION.

E1. Has this degradation affected you? YES ☐ NO ☐

(If NO, skip to section E)

E2. Has it had any effect on crop farming? YES ☐ NO ☐

E3. If yes, what are the effects?

1. Reduced supply of water for irrigation
2. Poor riverine soils
3. Poor quality water for irrigation
4. Reduced production for river irrigated farms.
5. Others (specify)____

E4. . Has it had any effect on Livestock keeping? YES ☐ NO ☐

E5: If yes, what are the effects?

1. Reduced fodder sources
2. Reduced alternative grazing land during droughts.
3. Reduced watering points for livestock.
4. Increase cost of water for zero grazing.
5. Increased fodder cost.
6. Others (specify)____

E6: Has this degradation affected water for domestic use? YES ☐ NO ☐

E7: If yes, what are the effects?

1. Reduced availability of clean water for washing and cooking.
2. Reduced availability of clean water for drinking.

3. Increased water borne diseases.
4. Increased cost of water for domestic use
5. Others
   (specify)____

E8: Has this degradation affected the riparian aesthetic value? YES ☐ NO ☐

E9: In what ways has it affected nature's beauty?

1. Reduced tour sites
2. Reduced children play grounds
3. Reduced riparian vegetation cover,
4. Changed vegetation cover,
5. Reduced variety of birds,
6. Reduced water pools,
7. Others
   (specify)____

E10: Has this degradation affected wildlife in the riparian zones? YES ☐ NO ☐

E11: In what ways has wildlife been affected?

1. Reduced birds variety and numbers,
2. Reduced fish availability
3. Reduced wild mammals,
4. Others (specify) ____

E12: has there been any other significant effect of degradation not mentioned above?

1. Reduced income
2. Increased human conflicts
3. Others (specify) ____

SECTION F: DEGRADATION INDICATORS:

F1: Are there things in your opinion which indicate that there has been degradation along the river?

YES ☐ NO ☐ ***(if NO, skip to section F).***

F2: What are some of these degradation indicators?

1. Disappearance of some plant species (*specify the species* ________________________).
2. Appearance of new plant species (*specify the species* ______________________________).
3. Increase of some plant species (*specify the species* _______________________________).
4. Decrease of some plant species (*specify the species* _______________________________).
5. Disappearance of bird species (*specify the species* ________________________________).
6. Disappearance of fish species (*specify the species* ________________________________).
7. Reduced water flow
8. Others (specify) ____

F3: If there has been reduced water flow what are the changes in river regimes after the April and December rains?

Rain season	**Past (in months)**	**Present (in months)**
April rains		
December rains		

<u>SECTION G: POSSIBLE INTERVENTIONS:</u>

G1: In your own opinion, can this degradation trend be managed? NO ☐ YES ☐

(if no, skip the section)

G2: What are some of the best interventions to reduce or terminate degradation?

1. Strengthening and implementation of conservation policies by the government
2. Sensitization and Participation of the community in riparian conservation
3. Support by non-governmental organisations in riparian conservation
4. Mitigation of climate change
5. Others (specify)____

G3: if G2:1Is true, what are some of the policies of the government that need to be checked?

1. Sand harvesting regulation policy
2. Riparian cultivation policies

3. Watershed land use policies
4. Livestock keeping policies
5. Soil conservation policies
6. Community inclusion in conservation policies.
7. Others (specify)____

G4: If G2:2 Is true, what are some of the areas in which farmers should be sensitized and involved?

1. Best agricultural practices in crop farming and livestock keeping
2. Water conservation significance and technologies
3. Soil and water conservation technologies
4. Riparian and watershed natural resource governance
5. Others (specify)____

G5: If G2:3 Is true, what are some of the areas in which NGOs should be involved?

1. Advocacy for government policies improvement and implementation
2. Sensitizing the community on their roles in riparian conservation
3. Support in implementation of riparian degradation and adaptation technologies.
4. Others (specify)____

G6: In the current degradation situation, what are some of the adaptation tactics you have used or desire to use to face the effects?

1. Sinking of boreholes,
2. Using borehole water
3. Water treatment
4. Shift from irrigation to rain fed agriculture,
5. Construction of sand dams
6. Roof and runoff water harvesting
7. Zero grazing with cultivated fodder (Specify fodder type________________)
8. Others (specify)______________________

G7: What are some of the main challenges in implementing mitigation and adaptation technologies?

1. Financial constraints
2. Political goodwill
3. Community willingness to participate
4. Age of willing community members
5. Others (specify)_________________

G8: in your own opinion, how can these challenges be mitigated?

1. Advocacy at the government level for riparian conservation involvement
2. Youth involvement in community work
3. Capacity building of community members in fund raising techniques
4. Lobbying for higher budgetary allocation in riparian conservation efforts
5. CSO involvement in riparian conservation efforts.
6. Others (specify)____

2.2 Key informant questionnaire

SOUTH EASTERN KENYA UNIVERSITY (SEKU)

An Investigation of Degradation level and Its Effects on The Riparian Ecosystems of Eastern Semi Arid Region of Kenya; A Case Study of Kaiti River, Makueni County.

All data gathered from this survey is totally confidential and will be used solely for academic purposes.

Informed Consent Form

A research is being undertaken to assess and document the causes, effects and key indicator species of degradation in the riparian ecosystems of the Semi Arid regions of Kenya with Kaiti River being the case of study. *The research is being carried out by* an environmental management masters student of South Eastern Kenya University namely Charles Kisima Kimani Reg. No. **I501/WTE/20248/2012,** ID.NO. **25872270**.

<u>KEY INFORMANTS CATEGORY</u>

<u>SECTION A: INTRODUCTION</u>

Respondent's name: ....

Name of Organization/Department: ……………………………………………………

Area of operation..

Designation: ....

Age: ....

Gender: ....

Level of education: ....

Years of service: ....

District of origin ___________________________________

1. What is your key role in this institution?

____

2. What are the key roles of your institution in the Kaiti watershed/ Makueni County?

____

____

____

3. Do you have any responsibility in Riparian degradation management? If yes what is the responsibility?

____

____

4. Has your organisation realised/noticed any degradation in Kaiti riparian ecosystem? YES ☐ NO ☐

5. If yes, please describe the level of degradation in the riparian ecosystem.

____

____

____

6. When did this degradation intensify or become remarkable?

____

SECTION B: CAUSES OF DEGRADATION

7. Has crop farming contributed to degradation in the riparian ecosystem? If yes, in what ways?

____

____

____

8. Has livestock keeping contributed to degradation in the riparian ecosystem? If yes, in what ways?

____

____

9. Has sand harvesting contributed to degradation in the riparian ecosystem? If yes, in what ways?

____

____

10. Are there illegal settlements along the Kaiti riparian ecosystem? If yes, what is their contribution to degradation?

____

____

11. How would you describe land use change in the Kaiti riparian ecosystem?

____

____

12. Has land use change contributed to degradation in the riparian ecosystem? If yes, in what ways?

____

____

13. Has there been remarkable deforestation in the riparian ecosystem and watershed? If yes how has it affected degradation?

____

____

14. Could climate change be a major cause in this degradation? If yes, in what ways?

____

____

15. Are there degradation control policies available for governance? If yes, which are they?

____

____

____

16. Have the policies been effective in achieving results? If yes which results so far?

____

____

If NO. What are the challenges?____

____

____

17. What are the other key causes of degradation in the Kaiti riparian ecosystem?

____

____

____

18. What are the primary factors fueling the causes of degradation and causing them to persist or increase?

____

____

____

SECTION C: EFFECTS OF DEGRADATION:

19. Has this degradation brought any negative effects? If yes, please explain the effects in the following areas.

Crop production ____

Livestock (e.g. fodder, water) ____

Bio diversity ____

Wildlife (e.g. birds, fish) ____

Economy (e.g. income) ____

Domestic water supply -____

Aesthetics/Nature____

Social cohesion ____

20. Which other areas have been negatively affected and how?

____

____

____

SECTION D: KEY INDICATORS

21. Are there reliable indicators of riparian degradation which have been in use or can be used for monitoring? If yes please specify in the following categories.

Plant indicators ____

____

____

Animal indicators ____

____

Physical indicators ____

____

Social indicators ____

____

Economic indicators ____

____

OTHERS

____

____

____

22. With the indicators in place, what should be done to ensure effective monitoring of riparian degradation?

____

____

SECTION E: POSSIBLE INTERVENTIONS

23. Can this degradation be managed successfully? If yes, which interventions do you propose? Through:-

The National government ____

____

The County government ____

____

The community ____

____

Development partners (CBOs, SHGs, NGOs, institutions) ____________________________

____

Others

____

____

____

24. As the mitigation goes on, what adaptation technologies can be introduced for survival of the people and livestock?

____

____

____

2.3. Focus Group Discussion questionnaire

SOUTH EASTERN KENYA UNIVERSITY (SEKU)

An Investigation of Degradation level and Its Effects on The Riparian Ecosystems of Eastern Semi Arid Region of Kenya; A Case Study of Kaiti River, Makueni County.

All data gathered from this survey is totally confidential and will be used solely for academic purposes.

Informed Consent Form

A research is being undertaken to assess and document the causes, effects and key indicator species of degradation in the riparian ecosystems of the Semi Arid regions of Kenya with Kaiti River being the case of study. *The research is being carried out by* an environmental management masters student of South Eastern Kenya University namely Charles Kisima Kimani Reg. No. **I501/WTE/20248/2012,** ID.NO. **25872270**.

FOCUS GROUP DISCUSSION CATEGORY

GROUP INTERVIEW GUIDE:

Context and causes

1. Do you know of the Kaiti River?
2. How many are members of the river's water resource associations?
3. How important has been the WRUA to you; Knowledge and river conservation?
4. How does the river help you as individuals/families/community?
5. Has there been changes in the river since 1970's?
6. What are the changes?
7. At what period did these changes become more pronounced and accelerated?
8. What has caused these changes?
9. Who can be held responsible for each of the changes?

Effects of degradation

10. Have these changes affected your lives economically/socially/healthwise?
11. What are the specific effects?
12. Are there fears if the trend continues?

    Indicators

13. What are some of the things that have indicated change in the integrity of the river system?

    Intervention

14. Who are the stakeholders responsible for taking care of the river directly and indirectly?
15. Have all these stakeholders been aware of the river degradation and its effects?
16. Do you think the stakeholders have done enough to contain further degradation?
17. If no? What has made the situation not be successfully contained to date?
18. What are your proposals for successful conservation of this river?
19. Which roles should each stakeholder play for successful conservation?

Appendix 3: Regression Analysis Tables

Crop farming regression

A simple regression test was used to test crop farming contribution to degradation.

The following hypothesis were tested:

H_0: There is a no significant relationship between degradation and the farming practices.

H_1: There is a significant relationship between degradation and the farming practices.

The dependent variable was degradation of River Kaiti riparian ecosystem while the independent variables were farming practices. The hypothesis tested if crop farming practices had contributed significantly to degradation of River Kaiti riparian ecosystem. The results of the regression model are presented in table 4.8 below.

Regression results for crop farming practices against degradation

	Beta Coefficient	R	R Square	F	P – value	Hypothesis Supported
Farming Practices	0.782	.921[a]	.849	9.4495	0.0003	Yes

The results in the table 4.8 illustrates the strength of the relationship between farming practices and degradation of River Kaiti riparian ecosystem. The R2 value of 0.849 shows that the independent variables (farming practices) accounts for 84.9% of the variations in degradation of River Kaiti riparian ecosystem.

ANOVA Results

The following table (4.21) provides the results of ANOVA for the relationship between predictor variables and degradation of River Kaiti riparian ecosystem.

ANOVA of the Regression

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	48.892	1	48.892	9.4495	0.0003
Residual	507.052	98	5.174		
Total	555.944	99			

a. Predictors: (Constant), Farming Practices.

b. Dependent Variable: Degradation of River Kaiti riparian ecosystem

The ANOVA results presented in the table 4.21 shows that the regression model has a margin of error of p value = 0.0003 which means the model has a probability of 0.03% of giving false prediction thus it was appropriate.

Coefficient of Determination

The table below provides the coefficient of determination on the relationship between the predictor variables and degradation of River Kaiti riparian ecosystem. The findings are as shown in table 4.22.

Coefficient of Determination

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
Model 1(Constant)	3.77	0.451		8.359202	0.005
Farming practices	0.782	0.121	0.146	6.46281	0.001

a. Dependent Variable: Degradation of River Kaiti riparian ecosystem

From the finding in Table 4.17, the study found that holding all independent variables at zero degradation of River Kaiti riparian ecosystem will be 3.77. Also, a unit raise in farming practices will lead to a raise in degradation of River Kaiti riparian ecosystem by 0.782 (p = 0.001). This depicts that at 5% level of significance and 95% level of confidence, the null hypothesis that, there is a no significant relationship between degradation and the farming practices, was rejected and the alternative hypothesis that there is a significant relationship between degradation and the farming practices was accepted.

Livestock keeping regression.

Regression on Relationship Between Livestock Farming Practices and Degradation

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.784[a]	.615	.623	.71454

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	0.049	1	.049	0.096	.002[b]
1	Residual	50.078	98	.511		
	Total	50.127	99			

Coefficients'

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
	(Constant)	3.482	.134		26.060	.000
1	livestock farming practices	. 211	.137	.216	.311	.002

Dependent Variable: degradation of River Kaiti riparian ecosystem

Predictors: (Constant), livestock farming practices

The results in table above shows that r = 0.784, implying a positive slope between the independent variable (livestock farming practices) and the dependent variable (degradation of River Kaiti riparian ecosystem). The R- Squared was 0.615, meaning that 61.5% of the variation in the degradation of River Kaiti riparian ecosystem was explained by variation in livestock farming practices. The other factors explained 28.5%. The ANOVA results indicated that the model was statistically significant at ($p<0.05$).

The results indicate that the p-value = 0.002≤0.05, t=26.060, p=0.002<0.05, r= 0.784 and r square=0.615. Hence based on these findings it can be stated that livestock farming practices have significance in degradation of River Kaiti riparian ecosystem.

$Y = \beta_0 + \beta_1 X_1 + \varepsilon$

can then be substituted as follows; $Y = 3.482 + 0.211X_1$

The beta value implies that for one-unit increase in livestock framing practices, degradation of River Kaiti riparian ecosystem increases by 0.211. This therefore confirms that livestock farming practices had a significant positive influence on the degradation of River Kaiti riparian ecosystem.

Sand Harvesting regression

Regression on Relationship Between Commercial Sand Harvesting and Degradation

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.812[a]	.659	.661	.69544

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	10.441	1	10.441	21.572	.000
1	Residual	47.432	98	.484		
	Total	57.873	99			

Coefficients'

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
	(Constant)	2.809	.157		17.845	.000
1	Commercial Sand Harvesting	.205	.144	.230	4.646	.000

Dependent Variable: degradation of River Kaiti riparian

Predictors: (Constant), Commercial Sand Harvesting

Results in table above shows that r = 0.812, implying a positive slope between the independent variable (commercial sand harvesting) and the dependent variable (degradation of River Kaiti riparian). The R- Squared was .659, meaning that 65.9% of the variation in the degradation of River Kaiti riparian was explained by variation in the commercial sand harvesting. The other factors explained 34.1%. The ANOVA results indicated that the model was statistically significant at ($p<0.05$). The results indicate that the p-value = 0.000≤0.05, t=17.845, p=0.000<0.05, r= 0.812 and r square=0.659. Hence based on these findings it was established that commercial sand harvesting has significance in degradation of River Kaiti riparian.

$Y = \beta_0 + \beta_1 X_1 + \varepsilon$

Can then be substituted as follows; $Y = 2.809 + 0.205X_2$

The beta value implies that for one-unit increase in commercial sand harvesting, degradation of River Kaiti riparian increases by 0.205. This therefore confirms that commercial sand harvesting had a significant positive influence on the degradation of River Kaiti riparian.

Other causes regression

Regression Between Other Causes and Degradation

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.721[a]	.520	.535	.71455

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.044	1	.044	.086	.001
	Residual	50.078	98	.511		
	Total	50.122	99			

Coefficients'

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.480	.548		23.508	.000
	Other Causes	.212	.141	.015	.292	.001

Dependent Variable: degradation in the Kaiti riparian ecosystem

Predictors: (Constant), Other Causes

Results in table above shows that r = 0.721, implying a positive slope between the independent variable (other causes) and the dependent variable (degradation in the Kaiti riparian ecosystem). The R- Squared was .520, meaning that 52.0% of the variation in the degradation in the Kaiti riparian ecosystem was explained by variation in other causes. The ANOVA results indicated that the model was statistically significant at ($p<0.05$).

Findings indicate that the p-value = $0.001 \leq 0.05$, $t=23.508$, $p=0.001<0.05$, $r= 0.721$ and r square=0.520. Hence based on these findings it was established that other causes have significance in degradation in the Kaiti riparian ecosystem.

$Y = \beta_0 + \beta_1 X_1 + \varepsilon$

Can then be substituted as follows; $Y= 3.480+ 0.212X_2$

The beta value implies that for one-unit increase in other causes, degradation in the Kaiti riparian ecosystem increases by 0.212. This therefore confirms that other causes had a significant positive influence on degradation in the Kaiti riparian ecosystem.

Effects on crop farming regression

Regression showing effects on crop farming

Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	If yes what are the effects?			6.200	4	.185	
	reduced supply of water for irrigation	-2.642	1.085	5.931	1	.015	.071
	poor riverine soils	-.924	1.138	.660	1	.416	.397
	poor quality water for irrigation	-20.181	23205.422	.000	1	.999	.000
	reduced production for river irrigated farms	-20.181	11147.524	.000	1	.999	.000
	Constant	-1.022	.389	6.907	1	.009	.360

a. Variable(s) entered on step 1: if yes what are the effects.

The Model fitted is:

$P = e\text{-}^{1.022 - 2.642x}/(1+ e\text{-}^{1.022 - 2.642x})$

This indicates that for every unit decrease in reduced supply of water for irrigation, there will be a corresponding decrease in the effects.

The model indicated that reduced supply of water for irrigation was the most significant effect that degradation had on crop farming (P-value= 0.015<0.05). The other factors were found not to have significantly been affected by degradation.

Effect on livestock regression

Regression showing effects on livestock keeping

Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	if yes what are the effects			6.291	4	.178	
	reduced fodder sources	-2.155	.859	6.291	1	.012	.116
	reduced alternative grazing land during droughts	-20.915	40192.970	.000	1	1.000	.000
	reduced watering points for livestock	-20.915	5741.853	.000	1	.997	.000
	increased fodder cost	-20.915	23205.422	.000	1	.999	.000
	Constant	-.288	.441	.426	1	.514	.750

a. Variable(s) entered on step 1: if yes what are the effects.

Effect on Water availability

Regression showing effects on water for domestic use.

Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	if yes what are the effects			8.287	3	.040	
	reduced availability of clean water for washing and cooking	-2.372	.824	8.287	1	.004	.093
	reduced availability of clean water for drinking	-20.356	10377.780	.000	1	.998	.000
	increased water borne diseases	-20.356	28420.722	.000	1	.999	.000
	Constant	-.847	.398	4.523	1	.033	.429

a. Variable(s) entered on step 1: if yes what are the effects.

Degradation indicators Chi square

Pearson's Chi square was used to test the hypothesis whether;

Chi-Square Test table

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.711[a]	3	.438
Likelihood Ratio	3.453	3	.327
Linear-by-Linear Association	1.118	1	.290
N of Valid Cases	100		

a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .44.

From the chi square table, it was identified that disappearance of plant species 38.0% (P-value= 0.502), reduced water flow 12.3% (P-value= 0.233) and disappearance of fish species 5.6% (P-value= 0.074) had a relationship with degradation happening in the region while disappearance of bird species 44.1% (P-value= 0.029) was significant. Therefore, we rejected the null hypothesis and concluded that there was relationship between the indicators and degradation happening in the riparian zone. (Table 4.37).