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Socio Economic Factors Contributing to Riparian Ecosystem Degradation along Kaiti River in Makueni County

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Authors' contributions

This work was carried out in collaboration among all authors. Author KCK played a pivotal role in designing the study, conducting statistical analyses, drafting the protocol, initiating the manuscript, and managing literature searches. Author KDP and Author OMA jointly managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

The degradation of riparian ecosystems threatens the livelihoods of communities that depend on these socio-ecological systems (SES) for their well-being. This is because; riparian ecosystems provide ecosystem services like fodder, timber, soil development, water regulation and habitat for wildlife. The riparian ecosystem in Kenya's Eastern Semi-Arid Region is one of the affected zones and information is required to understand the causes therein. This case study focussed on the Kaiti River in Makueni County to analyse the socio-economic factors leading to its riparian degradation. Data was collected between September 2018 to March 2019 using questionnaires, key informant interviews, focus group discussions and photographs. To analyse the data, SPSS version 26 interface with regression and correlation analysis was used to analyse the causes of riparian ecosystem degradation along the river. Crop farming was found to be a leading cause of degradation (R-Square =0.849, F (1, 99) =9.4495, p-value=0.0003$\leq$0.05) showing that farming

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accounts for 84.9% of the variations in degradation of River Kaiti riparian ecosystem. A calculated beta value implied that a unit raise in crop farming would lead to a rise in the degradation of the River Kaiti riparian ecosystem by 0.782 (p-value=0.001≤0.05). The results of the study also revealed that livestock farming (R-Square =0.615, β=0.211, p-value =0.002≤0.05), lack of riparian conservation awareness (R-Square =0.573, β=-0.757, p-value= 0.002≤0.05) and Commercial sand harvesting R-Square=0.659, β=0.205, p value=0.000≤0.05) significantly contribute to River Kaiti riparian ecosystem degradation. Other causes significantly contributing to degradation (R-Square =0.520, β=0.212, p-value=0.001≤0.05,) were poor natural resource governance, poverty, poor infrastructure, climate change and land use changes. The study concludes that awareness creation and control of human activity in the Kaiti riparian zone would significantly reduce riparian ecosystem degradation. A multi-stakeholder approach whereby the community takes centre stage in monitoring and implementing riparian conservation measures is recommended.

Keywords: Riparian degradation; riparian ecosystem; watershed management; socio-economic causes; riparian conservation; community awareness.

1. INTRODUCTION

Riparian ecosystems are among the most changed, degraded, and vulnerable ecosystems on Earth chiefly due to their location in the landscape and the intense human activities that happen along these regions [1]. Riparian habitats are adversely degraded by water use by humans since they are situated adjacent to major waterways. All over the world, riparian regions have been degraded or removed by forestry, agriculture, urbanisation, and other human land uses, with deforestation being the foremost driver of riparian habitat deterioration [2]. Key catchment areas have been adversely affected, changing the quality of water in aquatic ecosystems [3].

Many rivers are restrained by man-made dikes or levees affecting the functionality of riparian ecosystems. 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 [4]. In most cases, 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 [5]. Rapid climate change is also likely to modify groupings of species and environmental traits, creating novel habitats [6]. 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. Like land-management operations, water management decisions including water diversion, impoundment, or withdrawal can affect hydrological processes; lessen flooding of riparian floodplains, and transform riparian ecosystems [2].

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 [7]. 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 as a result of the excessive use of natural resources. These include significant algal blooms, waterborne illnesses, an invasion of water hyacinths, and oxygen reduction [8].

Recent land use studies in East Africa point to agriculture as the main cause of wetland degradation. Nzau et al., [9] 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 drylands 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 [10].

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 [10]. In a study by Malombe et al., [11], 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.

Understanding how gradually or locally human activities could scale up to damage local biotas is necessary in light of the present threats to global biodiversity [12]. This study sought to gather Empirical information on the causes of degradation in Kenya's semi-arid riparian ecosystems with the Kaiti River as a case study.

2. MATERIALS AND METHODS

2.1 The Study Area

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 Fig. 1.

Fig. 1. Map of Kenya showing the location of Makueni County
Source: Kenya National Bureau of Statistics, 2009

At the Southernmost point of the district, 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 watershed, is more productive agriculturally. In the district, drainage generally runs from west to east. The district has several rivers and streams. Wote Town and the citizens of the Kaiti Watershed receive water from the Kaiti River [13].

Makueni County is characterized by very variable precipitation. Good seasons alternate with dry periods, and changes in the onset of the rainy season make it difficult to maintain an adequate food supply. The city 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 higher altitude regions receive 800 to 1200 mm of rain per year. 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 [14]. High temperatures in low-altitude areas cause high evaporation [13].

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 but land use change has continuously reduced forested areas [15].

There are three main livelihood zones in Makueni, Mbooni, Nzaui and Kaiti sub-counties; 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 [13].

The County hosts six major watersheds as shown in Fig. 2. Among the watersheds, the Kaiti River watershed though the smallest in coverage is of key importance being the one that serves the county headquarters.

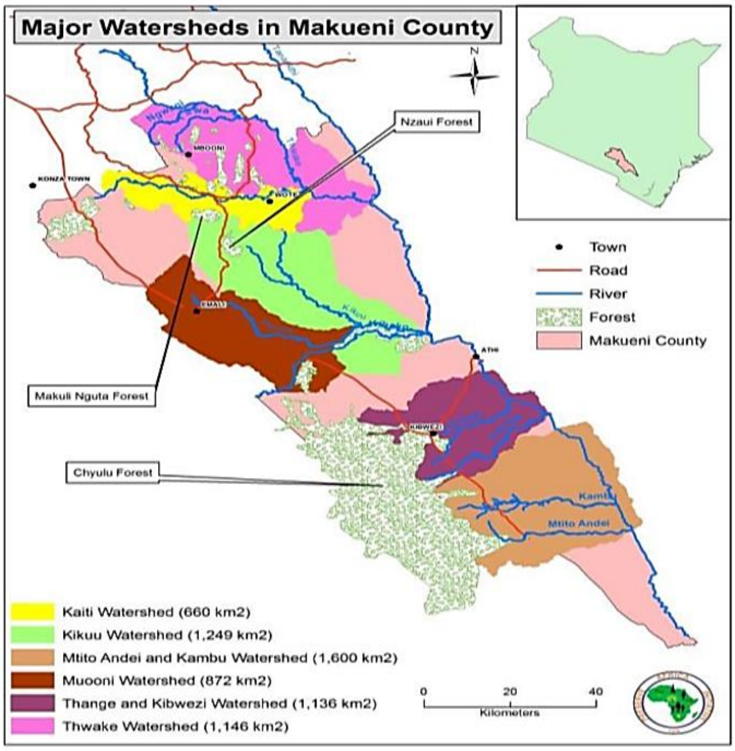

Fig. 2. Makueni county watersheds
Source PAFRI, Baseline survey maps (2012)

Data collection was conducted between September 2018 and March 2019 within the Kaiti River watershed (Fig. 3), encompassing an area of 660 km² situated between 10º 38´ South and 10º 51´ South, and 37°14´ East and 37°41´ East. The watershed includes Kilungu, Kee, Kalama, Kaiti, and Wote divisions. The river flows through Makueni and Kaiti Sub-Counties, extending to portions of Mbooni and Nzaui Sub-Counties as well [10]. Notably, the study area is characterized by a high population density, with 120, 116, and 248 persons per square kilometre in Kilungu, Kee, and Kalama divisions, respectively; exceeding the average density. The study area is shown in Fig. 3.

3. DATA COLLECTION

The study made use of a cross-sectional survey design that is both analytical and descriptive. To determine degradation causes, the survey collected primary and secondary data. For primary data, questionnaires were administered to respondents living along the Kaiti riparian ecosystem. The respondents consisted of households, community groups, local institutions, and key informants in the respective areas of investigation. Based on a sampling model by Magnani, a total of 100 respondents were selected, 20 in each Water Resource Management Zone (Kaiti River Water Resource User Associations (WRUA) boundaries).

The five Water Resource User Associations that have covered the watershed from the catchment down to its outlet were used. 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 employing an open and closed-ended questionnaire. Interviews to collect data were done in Kamba dialect to respondents of 18 years and above. 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.

Seven key informants were purposefully selected from relevant government and non-government institutions to validate data collected from households and FGDs. The selected government key informants were the 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, water resource management authority and one non-government key informant, Preserve Africa Initiative. The key informants were selected based on how frequently they directly interact with the riparian ecosystem, formally or informally, and their potential influence on the governance of the riparian resources.

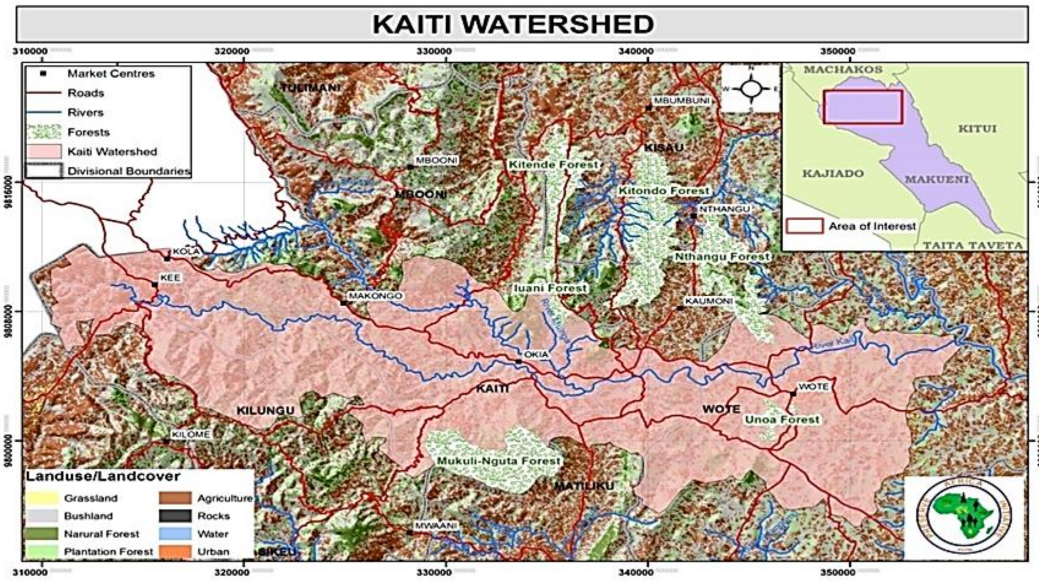

Fig. 3. Map of Kaiti Watershed

4. DATA ANALYSIS

Data analysis was done using SPSS version 26 and Excel sheet. SPSS version 26.0 was used to run a simple analysis of percentage representation per factor as well as run a regression analysis. Simple and Logistic regression models were used to show the relationship between the dependent variables and the independent variables that were used in the model and to draw conclusion on the significance of each parameter being tested.

5. RESULTS AND DISCUSSION

5.1 Bio-physical and Demographic Conditions

This study established that the Kaiti River riparian ecosystem has been greatly degraded with all the respondents confirming the existence of degradation (Table 1). This was endorsed by one of the key informants who added that there was a lot of illegal human activity especially farming along the riparian zone of the 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 (Table 1). This agrees with findings by Kieti et al., [10], who established that bio-physical changes had indeed taken place in the Kaiti sub-watershed.

The results of the survey pointed to the 1990s as the time degradation of the river resource accelerated more significantly. The majority of the key informants said that there had been a 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.

Eroded riverbanks were mentioned as the most noticeable evidence of riparian degradation as mentioned by 36.3% of the respondents. vegetation loss, exposed rocks, dry riverbeds, vanishing of wildlife once noticed in riparian zones and dried wells were also mentioned. 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. Richardson et al., [16] in their study agree that riparian degradation will largely be evidenced by changes in vegetation, water flow and water quality among others. Other evidence mentioned by key informants and FGD participants included drying river wells, reduced income levels from riparian land investments and resource conflicts.

The survey results (Fig. 4) show that most of the respondents were female 67.0% and that most of them (44.0%) were above 59 years. People aged below 40 years were only 14% indicating a weakness in the availability of young, energetic and creative members in community conservation projects. Mwei, [17] established that in many communities, youth make up much of the population; as a result, youth voices can be crucial expressions of the entire community's needs; Mwei's study revealed that young people's participation in community development can increase their self-esteem and connections with peers and communities.

The study revealed 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 low level of education in the Kaiti River riparian zone would mean a low status of living according to a study by Abuya et al., [18] who established that education and knowledge are key factors determining the living status of households.

The majority of the households (51.0%) had 4 to 6 members while the biggest household had more than 10 members (6.0%). Majority of the respondents (97.0%) owned between 0-10 acres of land. The majority of the respondents live and farm within less than 1 km from Kaiti River which coupled with the small land ownership and large family sizes indicates existing and potential human pressure on the river resource. A study by Olokeogun et al., [19], on the vulnerability of riparian ecosystems to human settlement found that vulnerability was highest in the high-density settlement areas of riparian zones.

Table 1. Respondents' Opinions on Presence, Significance, and Evidence of Riparian Degradation in Kaiti River

Parameters	Categories	Number of Respondents	Percentage	Cumulative frequency	Mean % (f)	Median
n = 100			**% (f) (n = 100)**	*Cf*		
1. 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		
2. 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		
3. 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		
4. 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		

The majority of the households (98%) in the Kaiti River riparian zone practiced agriculture as their occupation with only 2% in either formal employment or business. At least 95% of the respondents had annual income of between Kshs 0-300,000. An income level of below 100,000 per annum is considered as low according to the UNDP, [20] Human development report statistics. Kieti et al, [10] established that limited access to formal employment 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.

5.2 Riparian Conservation Awareness

The findings (Table 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. This agrees with Ndeti, [21] who found that training which is promoted through village public gatherings has impacted WRUA's water conservation performance in Kibwezi, Makueni County. This also agrees with a study by Thuo et al., [22] in the Southeastern region of Kenya which indicated that 68% of the sample households have soil and water conservation practices in their farms.

The majority of the respondents (70.0%) do not belong to any WRUA while 30.0% belonged to at least one WRUA (Table 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. According to Nyang et al., [23], it is easier when farmers collaborate in small groups during extension programmes, training, demonstration, and visits. However, a study by Mworia et al., [24], highlights that WRUAs have not been successful in sustainably managing riparian resources in the Tana Catchment area.

Fig. 4. A Sunburst Chart Showing Distribution of Demographic Characteristics among Respondents in the Kaiti River Watershed

Table 2. Level of understanding of riparian ecosystem conservation by respondents

Research Parameters	Categories	Number of Respondents	Percentage	Cumulative frequency	Median	Sig
n = 100			**% (f) (n = 100)**	*Cf*		
5. 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		
6. Membership to WRUAs	Yes	30	30	30		
	No	70	70	100		

Table 3. Table showing Model Coefficients for the 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?

A logistic regression model was used to test the significant effect of riparian conservation awareness on degradation. Table 3 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).

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 riparian region. According to Arif et al., [25], Worldwide ecological functions are at risk because of environmental illiteracy.

5.3 Crop Farming Practices

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

The following hypotheses were tested:

H_0: There is no significant relationship between degradation and farming practices.
H_1: There is a significant relationship between degradation and farming practices.

The dependent variable was the degradation of the River Kaiti riparian ecosystem while the independent variables were farming practices. The hypothesis tested if crop farming practices had contributed significantly to the degradation of the River Kaiti riparian ecosystem. The results of the regression model are presented in Table 4.

The results of the study showed a significant relationship between farming practices and the degradation of the River Kaiti riparian ecosystem $F(1, 99)=9.4495$, $p<0.05$, which indicates that farming practices play 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 (farming practices) account for 84.9% of the variations in the degradation of the River Kaiti 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 5 shows the farming practices that contribute to riparian lands.

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 farming are further aggravated by poor farming methods and a lack of understanding and awareness of the existing policies. A related study by Schmitt et al., [26] in Kitui County found that riparian encroachment reached 10 m of the river channel with native riparian vegetation taking only 12% of the riparian area, while farming took up to 52% of the zone in most areas. The FGD participants highlighted that farming is the main cause of large-scale 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. Richardson et al., 2007 state that cultivation of crops adjacent to the river may increase sediment deposition and eutrophication.

Table 4. 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

Table 5. A table showing Farming Practices Contributing to Kaiti 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

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., [3]. Buck et al., [27] enlists egg-shell thinning in birds as some of the effects of pesticides used in agriculture. However, fruit tree farming may also have a positive impact since fruit trees add to tree cover increasing rain interception and therefore reducing runoff. Fruit farming has been integrated with boundary tree planting and intercropping which has a resultant effect of increased tree cover, less soil erosion and better climate change adaptability [28].

5.4 Livestock Farming Practices

A simple regression test was used to test livestock keeping contribution to degradation.

The following hypotheses were tested:

H_0: There is no significant relationship between degradation and livestock keeping.
H_1: There is a significant relationship between degradation and livestock keeping.

The dependent variable was the degradation of the River Kaiti riparian ecosystem while the independent variables were livestock-keeping practices. The hypothesis tested if livestock-keeping practices had contributed significantly to the degradation of the River Kaiti riparian ecosystem. The results of the regression model are presented in Table 6.

The results of the study showed that livestock farming significantly contributed to the riparian degradation of River Kaiti, $F(1, 99)=0.096$, $p<0.05$, which indicates that livestock-keeping practices play 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-keeping practices) account for 61.5% of the variations in the degradation of the River Kaiti riparian ecosystem.

Among the livestock-keeping methods, cattle tethering was the most popular livestock-keeping method in the riparian zone. Tethering was the leading method represented by 65.0%, followed by zero grazing (31.0%) and free-range grazing (1.0%), (Table 7). Correlation analysis indicated a positive but insignificant relationship between the number of cattle kept and the method of livestock farming used ($r= 0.062$, $P= 0.555$).

It was revealed that 48.5% of the respondents didn't have enough pasture to graze cattle throughout the year while 51.5% meaning that chances of overgrazing in the riparian zone are high. This agrees with a study by Kanga et al., [29] 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., [30], 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.

Table 6. 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

Table 7. 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

Bear et al., [31] point out that grazing on the riverside could alter biogeochemical cycles resulting in drastic alterations in riparian vegetation composition and productivity, aquatic systems and water quality. This is especially true when cattle stocking rates are high. 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 Kauffman et al., [32], whose study noted that grazing had altered the structure and function of the riparian ecosystems of Northeastern Oregon in the United States of America. Richardson et al., [16] also add that grazing of livestock on riparian zones acts as a trigger for the proliferation of alien plants.

5.5 Commercial Sand Harvesting

A simple regression test was used to test sand harvesting's contribution to degradation.
The following hypotheses were tested:

H_0: There is no significant relationship between degradation and sand harvesting.
H_1: There is a significant relationship between degradation and sand harvesting.

The dependent variable was the degradation of the River Kaiti riparian ecosystem while the independent variables were sand harvesting. The hypothesis tested if sand harvesting had contributed significantly to the degradation of the River Kaiti riparian ecosystem. The results of the regression model are presented in Table 8.

The results of the study showed that sand harvesting significantly contributed to the riparian degradation of River Kaiti, $F(1, 99)=21.572$, $p<0.05$, which indicates that sand harvesting plays a significant role in shaping 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 River Kaiti riparian ecosystem.

Commercial sand harvesting had been witnessed by the majority of the respondents and 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. 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 which they use. Tractors harvesting sand from the river were observed near Wote town. Ashraf et al., [33] say 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.

5.6 Other Causes of Degradation

A simple regression test was used to test the contribution of these causes to degradation. The following hypotheses were tested:

H_0: There is no significant relationship between degradation and other causes.
H_1: There is a significant relationship between degradation and other causes.

The dependent variable was the degradation of the River Kaiti riparian ecosystem while the independent variables were other causes. 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 9.

Table 8. 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

Table 9. Regression results for 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

Table 10. Other Causes of Degradation in the Kaiti 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 results of the study showed that the abovementioned causes of degradation significantly contributed to the riparian degradation of the Kaiti River, $F(1, 99)=0.086$, $p<0.05$, which indicates that they play a significant role in shaping 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.

Among these causes, 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%) as shown in Table 10.

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., [34] 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 et al., [35] 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., [10] identified various factors contributing to riparian degradation, including land use changes, rapid population growth, poverty, climate change variability, and the absence of livelihood diversification. Small urban centres have also emerged along the rivers and according to Olokeogun et al., [19], 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 [36], is among the most damaging human activities in river basins, deeply modifying the physiography of watersheds by altering downstream flow and sediment transport. Matunda [37] 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 [38]. 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.

6. CONCLUSIONS

The study revealed that the Kaiti River has indeed 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 level of riparian conservation was found to be a significant factor influencing the degradation of the Kaiti River watershed. An increase in the level of riparian ecosystem conservation awareness, will significantly reduce the level of degradation in the Kaiti riparian region and vice-versa. 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 around the year for most farmers, led to overgrazing in the riparian zone, especially during dry spells leading to the 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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