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Impact of Land Use Activities on Itare River Bank Stability and Water Quality in South West Mau Water Catchment, Kenya

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Abstract: *This study was done to determine the impact of land use activities on Itare river bank stability and water quality, with a view to providing baseline information for management and conservation of Itare riparian zone. Specific objectives were to determine (i) Land management and agroforestry practices adopted by farmers along river Itare, (ii) Types of forests and common tree species on farms bordering river Itare and the state of riverbank stability, (iii) Types of livestock kept and grazing types used by farmers along river Itare, and (iv) River Itare water quality with respect to prevailing land use practices and in comparison to Kenya Bureau of Standards (KEBS) limits. Stratified random sampling of farmers along Itare River was done and semi-structured questionnaires were administered to them to determine the nature of land use practices in the zone. Water samples were collected from three sites along the river and selected water quality parameters were determined within forty eight (48) hours. Results indicated that the main land management practices are contour farming and terracing (76%) and agroforestry practices in the riparian zone are boundary planting (34%), woodlots (27%), and scattered trees on farms (27%). The common tree species on farms bordering the river are Eucalyptus spp (22%), Grevillea spp (21%) and Croton spp (17%). Also, 65% of the farmers kept cattle and 93.5% of the livestock are freely grazed. The riverbank was stable upstream and midstream but unstable downstream. Water pH, Dissolved Oxygen (DO), NO_3^-, NO_2^- levels and microbe total viable count (/100ml) at the three sites were lower than (or within) KEBS limits although turbidity increased downstream and DO at the three sites was significantly lower downstream (4.55 mg/L; p = 0.037). Iron concentration (mg/L) in the upstream sections of the river was significantly lower than that in the downstream (2.86 mg/L; p = 0.008). Escherichia coli counts were above KEBS limit downstream (2 counts/ 100 ml). Itare riverbank at the downstream site is unstable and degraded due to intense land use activities, which also has lead to low water quality downstream, especially in terms of E. coli counts. Water from the river at the upstream and midstreams secctions is, however, safe for drinking. This study recommends public campaign for riparian zone protection and ecologically sound anthropogenic waste management downstream of River Itare.*
Keywords: *Landuse, Riverbank, Mau, Catchment, Itare*

I. Introduction

Land use types and water quality are closely related and there are evidences across the globe indicating marked differences in the level of impact of land use activities on water quality [1, 2, 3]. It is, however, necessary to determine the status of such biophysical relationships for a particular region in the face of ever changing climate, human population and increased demand for ecosystem services with associated environmental degradation. Kenyan human population, for instance, increases at an annual rate of 2.8% and is projected to reach 51 million by 2025. It is currently about 38 million, having grown from just eight million in 1960 [4]. The proportion of Kenyans living in urban areas also increased from 7.4 % in 1960 to 21.3% in 2007 and it is projected that 33% of Kenyans will live in urban areas by 2030 [5]. This implies needs for increased food production as well as other amenities, all of which have a direct impact on the availability, quantity and quality of water.

The Mau Forest Complex, covering over 400 000 ha, is Kenya's largest closed canopy forest ecosystem and the single most important water catchment in the Rift Valley and western Kenya. It encompasses seven forest blocks, namely the Mau Narok, Maasai Mau, Eastern Mau, Western Mau, Southern Mau, South West Mau and Transmara regions. It is the largest water tower in the region, being the main catchment area for 12 rivers draining into Lake Baringo, Lake Nakuru, Lake Turkana, Lake Natron and the Trans-boundary Lake Victoria [6, 7]. Like other "water towers" of Kenya (i.e. Mount Kenya, the Aberdare Range, Mount Elgon, and the Cherangani Hills) the forest complex comprises montane forests that are surrounded by the most densely populated areas of the country since they provide enough water for intensive agriculture and urban settlements [8]. Mau forest complex supports key economic sectors in Kenya including energy, tourism, agriculture, and water supplies for settlements. In some parts of the Mau, forested and large-scale farm areas have been converted mainly into srnall-scale mixed agriculture and human settlements and these changes have impacted negatively on the ecological integrity and hydrologic processes in the watershed [9].

South West Mau forest is drained by several tributaries of river Sondu, including river Itare, passing through a mosaic of highly productive agricultural region and human habitation. The rivers that drain the catchment on the eastern side of Lake Victoria constitute about 37.5% of the total surface runoff entering the lake. In addition, preliminary mass balance has shown that 90% of the total phosphorus load is introduced to the lake through the rivers and their watersheds have become under increasing threat of degradation due to an expansion of rain-fed and irrigation agriculture [10, 11].

Crop and livestock production are dominant land uses in the upper catchments of most of Kenyan rivers. While these enterprises are valued for their socio-economic significance, there is concern over their impact on other ecosystem services in major water catchments in the country. The character of streams and rivers reflect an integration of physical and biological processes occurring in the catchment [12]. Landscape properties that contribute most directly to the structure and function of adequate systems include prevailing climate, catchment and riparian landuse or cover patterns, channel slope and aspect, quartenary and bedrock geology, and hydrography [13, 14]. It is on account of the potential for river catchment and bank degradation that this study was undertaken to collect baseline data on land use activities along the river.

This study was, therefore, done to determine the impact of land use activities on Itare river bank stability and water quality in South West Mau water catchment, with a view to providing baseline information that may be used by various ecosystem management stakeholders in formulating appropriate community based land use practices for the management and conservation of the Itare riparian zone. Specific objectives were to determine (i) Land management and agroforestry practices adopted by farmers along river Itare, (ii) Types of forests and common tree species on farms bordering river Itare and the state of riverbank stability, (iii) Types of livestock kept and grazing types used by farmers along river Itare, and (iv) River Itare water quality with respect to prevailing land use practices and in comparison to Kenya Bureau of Standards (KEBS) limits.

II. Materials and Methods

2.1. Study area description

This study was done in South-West Mau forest complex (Kenya) along Itare river course. The river drains through Bureti and Konoin Districts (covering Kimulot, Konoin, Bureti and Roret administrative divisions) lying between latitude 0^0 25’ and 0^0 43’ South and longitudes 35^0 05’ and 35^0 35’ East [15]. The land generally slopes to the west and is characterised by undulating topography, giving way to flattened terrain interspersed by hills to the south and west, with slope ranging from 2% in the plains and 30% at foothills. The top soil clay to clay loam in texture with friable consistence, weak to moderately sub-angular blocky structure and pH ranging from 5.6 to 6.4 [6, 7]. Mean annual rainfall is 1300 mm and mean monthly rainfall ranges from 30 mm to over 120 mm. Rainfall is highest in Kimulot and Konoin zones which form the upper catchment of river Itare. Rainfall is abundant and well distributed throughout the year but for the short dry spell in the months of January and February. The lowest rainfall is recorded in January while the highest is recorded in April. Mean annual temperature varies with altitude zone as follows: 1100 – 1300 m zone (21 – 23 ^oC), 1300 – 1500 m zone (20 – 22 ^oC), and 1500 – 2000 m zone (17 – 20 ^oC) [16].

2.2. Evaluation of Land Use Practices

A reconnaissance survey was carried out to ascertain land use activities along Itare river catchment and identify possible sampling positions. The river was partitioned into three sites basing on land uses: Forested on both sides, tea plantations on both sides and lastly settlement on both sides of the river.This was followed by a participatory survey using a structured questionnaire in order to determine and describe detailed land use activities along the river catchment. The survey captured information on the following: Demographic information of the riparian farmer community, Land management practices, Agroforestry practices, Types of forests on farms bordering the river, tree species on farms bordering the river, types of livestock kept by farmers near the river, and grazing type.

2.3. Water Quality Assessment

2.3.1 Water Sample Collection

Water samples were collected from pre-determined sections of the river based on type of land-use practices along the river. Specifically, samples were collected at sections of the river where: (i) Undisturbed natural forest cover exists along the river (near the source of river), i.e. **Site A at Embomos Itare Forest**, (ii) Perennial crop cultivation (such as tea) occurs along the river, i.e. **Site B at Kaptien**, and (iii) Arable farming practices are carried out along the river, i.e. **Site C at Mosore Bridge, Roret**. These sites are ordered from the upper catchment downstream. At a particular site water samples were collected at the middle (centre), and at the edges (near riverbank) of the river. That is, three samples were collected at a particular point in a section of the river. There were two sampling points per site, giving a total of six (6) sampling points. Since three water samples (two near the river bank and one at the middle of the river) were taken at each sampling point, there were eighteen (18) water samples in total.

2.3.2 Water Quality Determination

The following quality parameter of Itare river water samples were determined within forty eight (48) hours at Government Chemists' Department Laboratory, Western Kenya Region (Kisumu): (i) pH, (ii) Turbidity, (iii) Concentration of oxygen (dissolved) (mg/L), (iv) Concentration of nitrogen compounds (Nitrates and Nitrites) (mg/L), (v) Concentration of heavy metals like Fe, Cu, Pb, and Hg (mg/L), (vi) Total viable count of microbes per 100ml of water, and (vii) *Escherichia coli* count per 100 ml of water.

2.4 Data summarization, analysis and presentation

Means (±SE) of the resulting data were summarized in relation to the river sites, depicting prevailing land-use practices along the riparian zone (,i.e. Closed canopy forest on either side of the river and occurring to the upstream (Embomos-Itare Forest), tea plantation on either side (Kaptien), and cultivated land on either side and occurring to the downstream (Mosore Bridge)) and segregated to river sections at a given site, i.e. Left Edge of the river, Middle of the river, and Right edge of the river. The means were then subjected to one-way ANOVA (∞=0.05) using SPSS version 22and separated by Least Significant Difference (LSD) [17] to determine the influence of the land-use practices on the water quality parameters. Results were presented as charts, graphs and tables.

III. Results and Discussion

3.1. Demographic information of the riparian farmer community

Communities living around Itare River have free hold land tenure (100%) and farming is their main source of income (100%), with wood fuel being their main source of energy (100%). Fifty eight percent (58%) of the sampled farmers own over 5 acres of land with 42% of them having 2-5 acres (Fig. 1). Farmer household size ranged from two to over ten with 44% of the sampled farmers having 5-7 persons per household. Also, nearly all households (99%) had male heads and all individuals sampled had basic education with 77% of them having at least secondary school level of education.

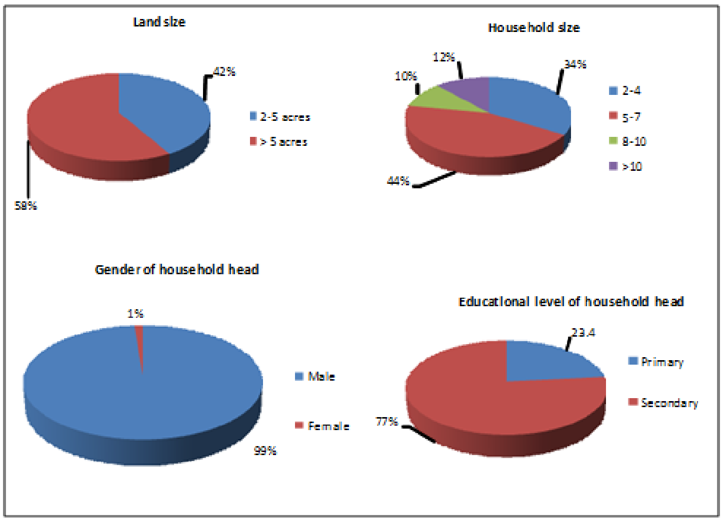


Figure 1: Land size, household size, gender and educational level of household heads of communities living around Itare River in South West Mau, Kenya

3.2. Land management and agroforestry practices adopted by farmers along river Itare

Main land management practices adopted by farmers along river Itare are presented in Fig. 2 and the main agroforestry practices adopted by the farmers are presented in Fig. 3. Contour farming and terracing are the main land management practices adopted by 48% and 28% of farmers respectively while others (24%) used filter strips/ stones /grass residues in their farms for soil and water conservation. The proportion of farmers that adopted various agroforestry practices were as follow: boundary planting (34%), woodlots (27%), scattered trees on farms (27%), hedgerow intercropping (3%) and others (9%). General steep slope could be a factor influencing the adoption of contour farming as a measure to control soil erosion in South West Mau (Fig. 2).

High population coupled with intensive agriculture may be the reason for high adoption of boundary planting as an agroforestry practice (Fig.3).

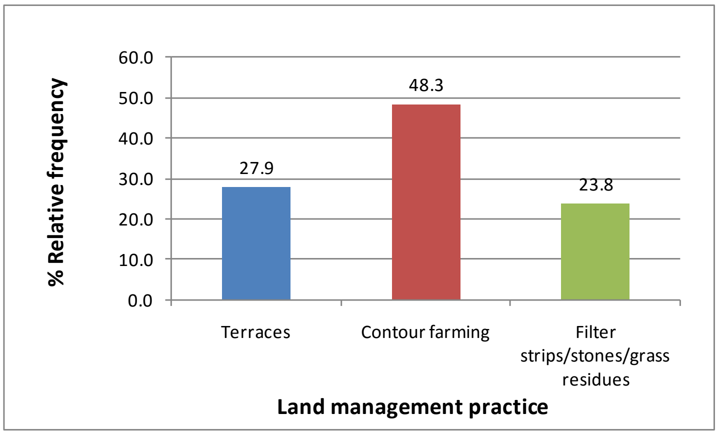


Figure 2: Main land management practices adopted by farmers along river Itare , South West Mau, Kenya

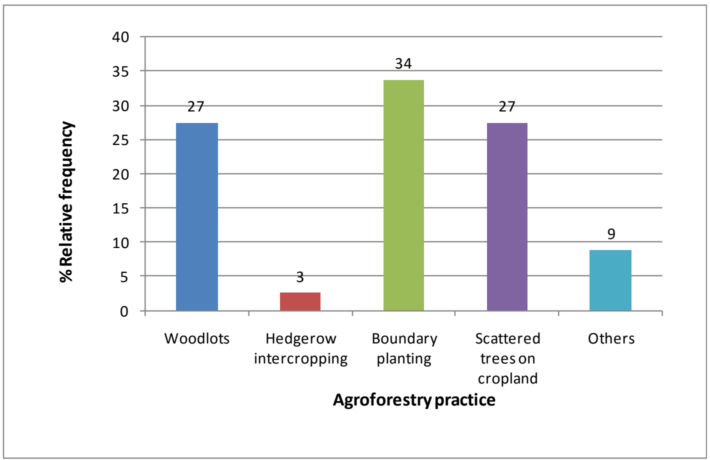


Figure 3: Main agroforestry practices adopted by farmers along river Itare, South West Mau, Kenya

3.3. Types of forests and common tree species on farms bordering river Itare and state of the riverbank stability

Both natural and planted forests of varied acreage are managed by farmers along river Itare with 62% of the farmers having planted forests and 38% of them having portions of natural forests within their own land (Fig. 4). Three tree species were the most preferred (60%) for planting on farms bordering the river, and these were *Eucalyptus saligna* (22%), *Grevillea robusta* (21%) and *Croton spp* (17%) (Fig. 5).

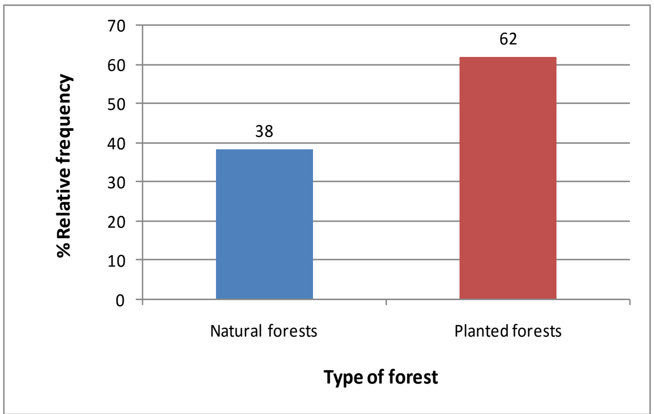


Figure 4: Proportions of farmers having different types of forests (%) along river Itare, South West Mau, Kenya

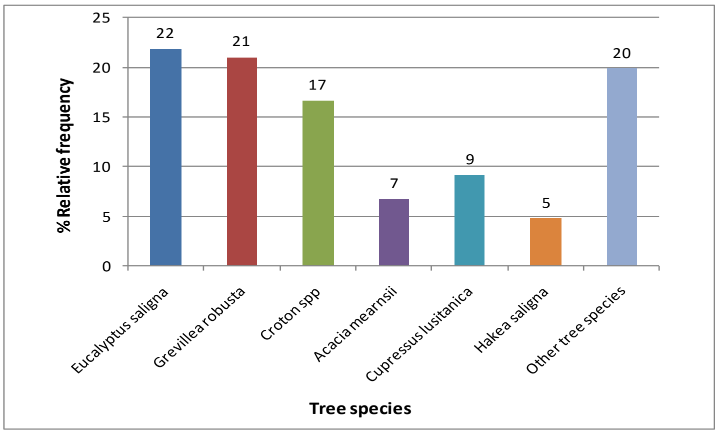


Figure 5: Tree species planted or managed by farmers on farms bordering river Itare, South West Mau, Kenya

Land sizes, population growth and land use changes can be linked to environmental conservation [18]. Population growth seen from relatively large household sizes in the study area is likely to result into land sub-divisions and intensification of land-use. Likely consequence include deforestation, overgrazing, conversion of natural vegetation areas to cultivated land and introduction of crops (woody and non-woody) that are considered of immediate subsistence need and high commercial value. This can be seen from the tree species that have been planted – *Eucalyptus spp, Grevillea robusta,* and other fast growing exotic species (Fig. 5) among the dominant species planted on farms. These are mainly planted as commercial species to be sold to tea factories for fuel wood and for timber to timber merchants.

The Itare riverbank was stable where either closed canopy forest occurred on either side of the river or no cultivation was done near the river bank, as shown in Plate 1(a_1) and Plate 1 (a_2) at Embomos-Itare Forest and Kaptien sites respectively. Some sections of the two sites, however, experienced slight human activities like logging and cutting of saplings near the river with negligible negative impact on riverbank stability as shown in 1(b_1) and Plate 1 (b_2) Kaptien sites.

There were indicators of compromised riverbank stability at Mosore Bridge site due to high intensity of human activities characterised by arable farming and livestock keeping. Watering of cattle at the river, cultivation near the river and harvesting of murram (though not in many sites) were some of the factors that lead to degradation of riverbank stability at Mosore bridge site as shown in plate 2.

Plate 1: A well preserved riparian vegetation (a_1 and a_2) and degraded sections (b_1 and b_2) of river Itare, South West Mau, Kenya

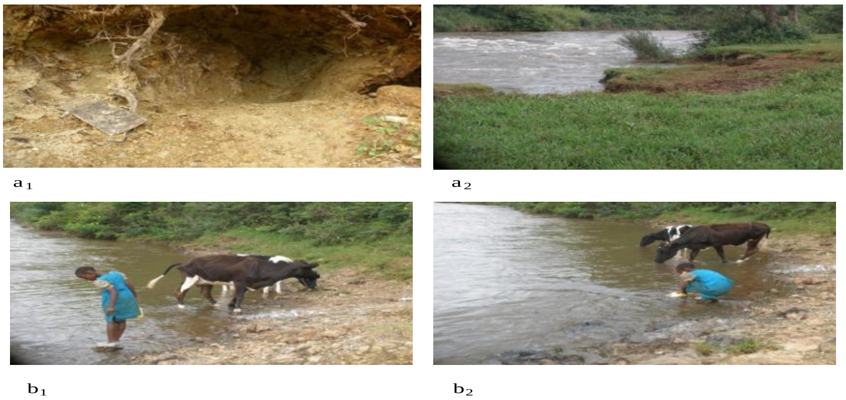


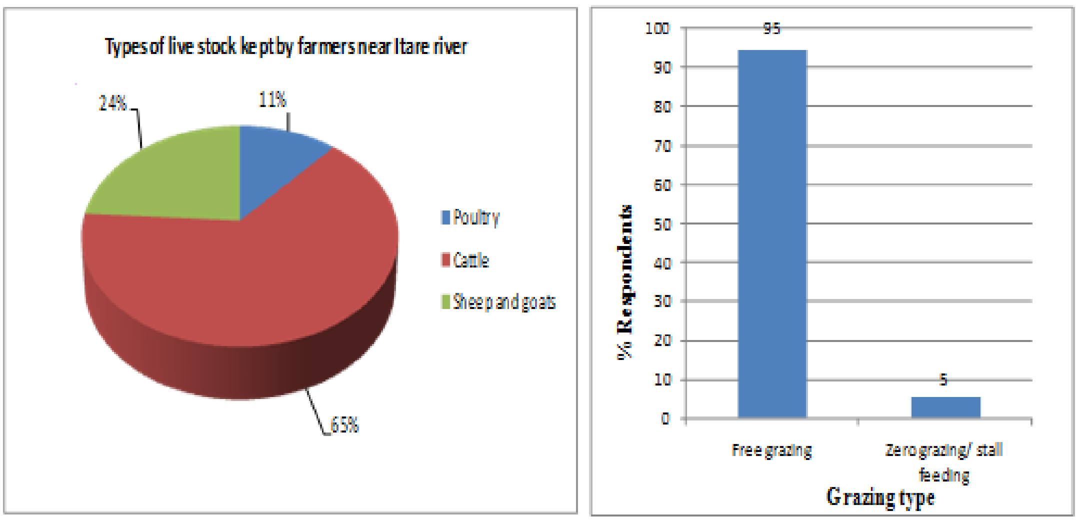
Plate 2: Murram harvesting near the river (a$_1$), unstable riverbank due to grazing and watering of cattle at and near Itare river (a$_2$, b$_1$ and b$_2$) at Mosore Bridge, South West Mau, Kenya

Narrowing of stream channel has been found to increase flow velocity, causing accelerated bank and channel scouring downstream. Such problems have been solved by construction and storm repairs involving slope reshaping and rootwad installation, especially in North Dakota in United States of America [19].

3.4. Types of livestock kept and grazing type used by farmers along river Itare

The main types of livestock kept by farmers along river Itare are cattle, sheep and goats, and poultry. Majority of the farmers (65%) keep cattle (Fig. 6a), of which 95% adopt free grazing of their livestock (Fig. 6b). Farming is the main economic activity with commercial agriculture focusing mainly on tea in the upper catchment, and diversified with small scale horticulture in the lower areas (Roret). Land sub-divisions, increase on farm subsistence needs, including fuel wood and other tree based products, are likely to lead to increased vegetation clearance, including up to the river banks, and leading to degradation of the banks.

Many farmers in the region keep dairy cattle for both domestic milk consumption and commercial purposes. Increasing rate of urbanization in the region has provided ready market for dairy products, although dairy farming as an economic activity is still secondary to tea growing. Large tracts of land are under tea, leaving very little space for other socio-economic activities like goat and sheep rearing. Under such scenario, one would expect that many farmers in the region practice zero-grazing. Contrary to that, free grazing in the region is common, generally on paddocks set aside on a rotational basis and, sometimes, communal grazing done on fallow land even though the land may legally belong to a particular farmer. This means that any fallow land near the river is likely to be used by all villagers for grazing and watering of their cattle, further increasing the potential for soil erosion and riverbank degradation.



(a) (b)

Figure 6: **(a)** Proportion (%) of farmers along river Itare that keep cattle, sheep, goats and poultry, and **(b)** the proportion (%) of farmers that adopt different grazing types along the river in South West Mau, Kenya

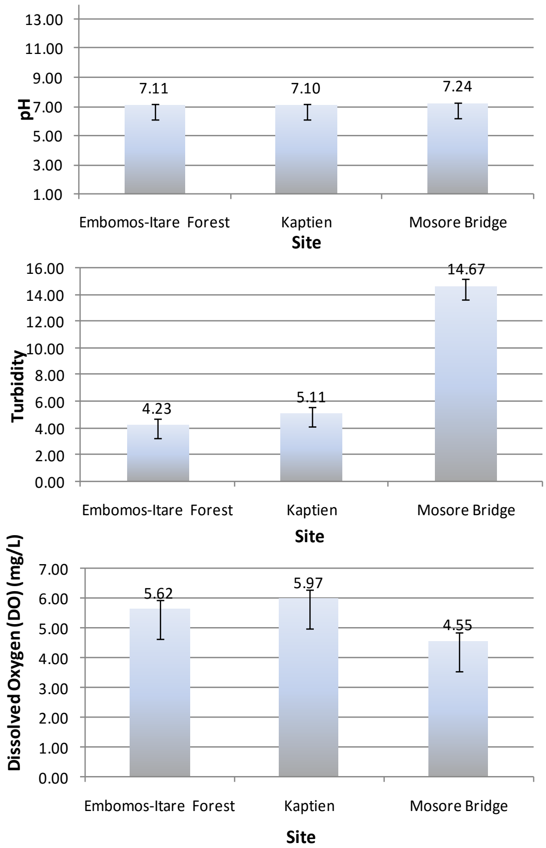
3.5. River Itare water quality with respect to prevailing land use practices in South West Mau, Kenya

3.5.1. Hydrogen ion concentration (pH), Turbidity and Dissolved Oxygen (DO) at different sites along River Itare in South West Mau, Kenya

Results on levels of Hydrogen ion concentration (pH), Turbidity and Dissolved Oxygen (mg/L) at three sites (Embomos-Itare Forest, Kaptien and Mosore Bridge) along River Itare in South West Mau, Kenya are presented in Fig. 7 and Tables 1a and 1b.

Water pH at the three sites (7.11, 7.10 and 7.24 respectively) were not significantly different ($p = 0.371$; Table 1a) and were within the acceptable range as per Kenya bureau of standards (KEBS) limits of 6.5 – 8.5. Hydrogen ion concentration (pH) of water not only affects directly the diversity and distribution of organisms, but also determines the nature of many chemical reactions that occur in the environment [20]. The results indicate that the water pH condition doesn't pose any risk to environmental health.

Turbidity significantly increased downstream from 4.23 at Embomos-Itare Forest site to 14.67 at Mosore Bridge site (Fig.7; $p = 0.000$). The high turbidity levels at Kaptien and Mosore Bridge are attributed to increased soil erosion due to intense land cultivation downstream with corresponding reduction in vegetation cover. The high levels also indicate intense river bank degradation at the two sites, and are cause for concern since they are much greater than KEBS acceptable level (Turbidity = 5). Turbidity, an optical property of water, causes light to be scattered or absorbed in the water, resulting in a decrease in water transparency [20] and this adversely affects the distribution and intensity of photosynthesis. High concentrations of particulate matter affect light penetration and productivity, recreational values, and habitat quality, and cause lakes to fill in faster. In streams, increased sedimentation and siltation can occur, which can result in harm to habitat areas for fish and other aquatic life. Particles also provide attachment places for other pollutants, notably metals and bacteria. For this reason, turbidity readings can be used as an indicator of potential pollution in a water body [21], and this is likely the case for Kaptien and Mosore bridge sites along River Itare in South West Mau, Kenya.



KEBS LIMITS
(KS 05-459: Part 1:1996)

Parameter	Limit
pH	6.5 - 8.5
Turbidity	5
Dissolved Oxygen (DO) (mg/L)	> 1

Figure 7: pH, Turbidity and Dissolve oxygen (DO) levels at different sites along river Itare, South West Mau, Kenya.

Dissolved oxygen (DO) level at the three sites was significantly lower downstream (Mosore Bridge) (4.55 mg/L; $p = 0.037$). DO levels at the three sites were greater than one (Fig. 7) and, therefore, were within KEBS acceptable limits, although the levels at Kaptien and Mosore bridge sites were significantly different ($p = 0.015$; Fig. 7 and 1b). DO in water affects the oxidation-reduction state of many other chemical variables, such as nitrates and ammonia, sulphate and sulphite, and ferrous and ferric ions. Also, a low DO content is often an indicator of organic pollution [20]. High turbidity and relative low DO levels at Mosore Bridge indicate organic pollution in the river, and this requires root cause analysis and adoption of environment-friendly land use practices as a mitigation strategy.

3.5.2. Nitrates, Nitrite and Iron (other metals) Concentrations (mg/L) at different sites along River Itare in South West Mau, Kenya

Results on concentrations (mg/L) of nitrates, nitrites and Iron (other metals) at three sites (Embomos-Itare Forest, Kaptien and Mosore Bridge) along river Itare in South West Mau, Kenya, are presented in Fig. 8 and Tables 1a and 1b.

Nitrate (NO_3^-) concentrations at the three sites were lower than KEBS limit of 10 mg/L (Fig. 8), hence were tolerable in terms of environmental health, i.e. river Itare water is safe for drinking with respect to nitrate concentration. NO_3^- concentration at the sites were significantly different (p =0.001; Table 1a) and the concentration at Kaptien (0.74 mg/L) was significantly lower that at either Embomos-Itare Forest or Mosore Bridge (p = 0.05; Table 1b). Low water NO_3^- concentration at Kaptien may have been due to greatly reduced soil erosion and sedimentation as a result of heavy vegetation cover by surrounding tea plantations. Presence of high amount of organic matter upstream (Embomos-Itare Forest) and high level of sedimentation downstream (Mosore Bridge), due to soil erosion as evidenced by high turbidity, are possible reasons for relatively high NO_3^- concentrations at those sites. This also may partly explain the low levels of dissolved oxygen at Mosore Bridge. Basically, any excess nitrate in the water is a source of fertilizer for aquatic plants and algae [22]. In many cases, the amount of nitrate in the water is what limits how much plants and algae can grow. The nitrate concentration in surface water is normally low (0–18 mg/l) but can reach high levels as a result of agricultural runoff, refuse dump runoff or contamination with human or animal wastes. The concentration often fluctuates with the season and may increase when the river is fed by nitrate-rich aquifers [23]. In most countries including Kenya, nitrate levels in drinking-water derived from surface water do not exceed 10 mg/l. With NO_3^- concentration in the three sites ranging from 0.74 to 1.61 mg/L (Fig. 8), river Itare water is safe for drinking.

Nitrite (NO_2^-) concentrations at the three sites (0.004 mg/L at Embomos-Itare Forest, 0.004 mg/L at Kaptien and 0.005 mg/L at Mosore Bridge) were lower than KEBS limit of 0.1mg/L (Fig. 8) and were not significantly different (p =0.229; Table 1a). Nitrite levels in drinking-water are usually below 0.1 mg/l. In 1993, a maximum value of 0.21 mg/l was detected in the Netherlands [23, 24]. In Kenya, maximum nitrite level of 0.1 mg/L in drinking water is acceptable, hence the river Itare water at the study sites is safe for drinking.

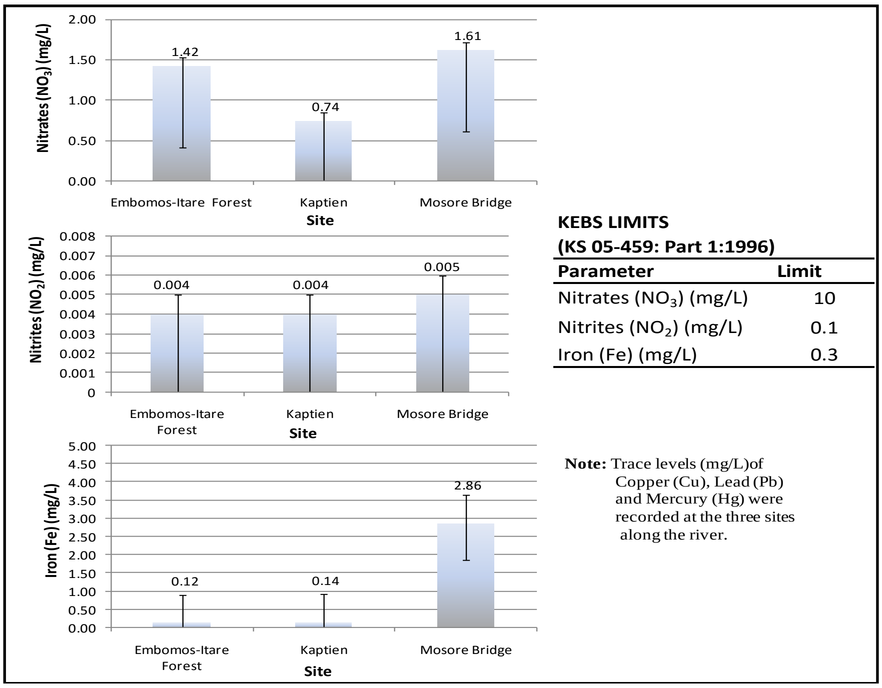


Figure 8: Nitrate, nitrite and iron (other metals) concentrations at different sites (Embomos-Itare Forest, Kaptien and Mosore Bridge) along river Itare, South West Mau, Kenya.

The concentration of iron (mg/L) in the upstream sections of Itare river water (Embomos-Itare Forest (0.12 mg/L) and Kaptien (0.14 mg/L)) were significantly lower than that downstream (Mosore Bridge (2.86

mg/L)) (Fig. 8; p = 0.008). According to World Health Organization [25], cconcentrations of iron in drinking-water are normally less than 0.3 mg/litre but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution. Also, reported daily intakes of iron in food range from 10 to 14 mg while drinking-water containing 0.3 mg/L would contribute about 0.6 mg to the daily intake. Iron is an essential element in human nutrition and estimates of the minimum daily requirement for the element depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day [26]. The average lethal dose of iron is 200–250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight [25, 27]. Although iron concentration (mg/L) in the downstream (Mosore Bridge; 2.86 mg/L) was higher than the maximum KEBS limit of 0.3 mg/L. If 0.3 mg/L in drinking water contributes about 0.6 mg to daily intake in human, then 2.86 mg/L would contribute about 5.72 mg/L of iron, which is within the acceptable range of 10 to 50 mg/day. This shows that river Itare water is safe for drinking although the cause of marked increase in iron levels from 0.12 mg/L upstream to 2.86 mg/L downstream needs to be determined. Use of pesticides in the surrounding cultivated land could be one of such causes of relatively high iron concentration in the river downstream. Trace levels (mg/L) of copper (Cu), Lead (Pb) and Mercury (Hg) were recorded in the three sites along the river.

3.5.3. Microbe total viable count and *E. coli* count (/100ml) at different sites along river Itare, South West Mau, Kenya.

Results on microbe total viable count and E. coli count (/100ml) at three sites (Embomos-Itare Forest, Kaptien and Mosore Bridge) along river Itare in South West Mau, Kenya, are presented in Fig. 9 and Tables 1a and 1b. Microbe total viable count (/100ml) at the three sites were lower than KEBS maximum limit (100 count/ 100 ml; Fig. 9) and significantly different (p = 0.005; Table 1a) with the lowest count recorded at Kaptien site. Similar trend, though not significantly different, was recorded with respect to Escherichia coli counts (i.e. 0 count/ 100 ml of water at Kaptien while 1 count/100 ml at Embomos-Itare Forest, and 2 counts/ 100 ml of water at Mosore Bridge; p = 0.129). Since KEBS limit for E. coli count is 0 count/ 100ml of water, the Itare river water downstream (Mosore Bridge) is unsafe for drinking unless treated against the microbes. Reasons for low Microbe total viable count (/100ml) midstream (Kaptien; 34 counts/ 100 ml) and 0 count/ 100ml of water for E. coli at Kaptien need to be investigated. Because the upstream section is surrounded by dense natural forest, and midstream section is surrounded by vast areas of tea plantation, with greatly reduce human settlement, while downstream section of the river is surrounded by arable land interspersed with human settlement, it is expected that human waste and other anthropogenic causes influence the relatively high microbe total viable count and E. coli count (/100ml) downstream (Mosore Bridge) along river Itare, South West Mau, Kenya.

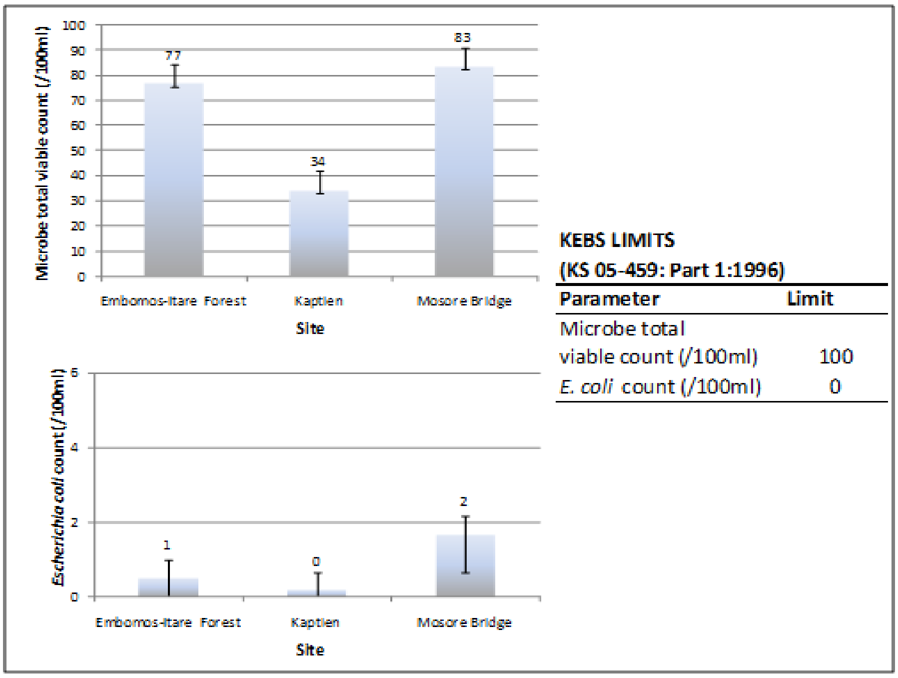


Figure 9: Microbe total viable count and *E. coli* count (/100ml) at different sites along river Itare, South West Mau, Kenya.

Table 1a: One-way ANOVA of River Itare water quality parameters with respect to prevailing land use practices at three sites (Embomos-Itare Forest, Kaptien and Mosore Bridge) in South West Mau, Kenya

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**p**
pH	Between Groups	0.067	2	0.034	1.060	0.371
	Within Groups	0.475	15	0.032		
	Total	0.542	17			
Turbidity	Between Groups	402.399	2	201.199	170.891	0.000
	Within Groups	17.660	15	1.177		
	Total	420.059	17			
Dissolved Oxygen (DO) (mg/L)	Between Groups	6.525	2	3.262	4.122	0.037
	Within Groups	11.872	15	0.791		
	Total	18.397	17			
Nitrates (NO3) (mg/L)	Between Groups	2.539	2	1.270	12.539	0.001
	Within Groups	1.519	15	0.101		
	Total	4.058	17			
Nitrites (NO2) (mg/L)	Between Groups	0.000	2	0.000	1.626	0.229
	Within Groups	0.000	15	0.000		
	Total	0.000	17			
Iron (Fe) (mg/L)	Between Groups	29.849	2	14.925	6.773	0.008
	Within Groups	33.053	15	2.204		
	Total	62.902	17			
Copper(Cu) (mg/L)	Between Groups	0.000	2	0.000	.	.
	Within Groups	0.000	15	0.000		
	Total	0.000	17			
Lead (Pb) (mg/L)	Between Groups	0.000	2	0.000	.	.
	Within Groups	0.000	15	0.000		
	Total	0.000	17			
Mercury (Hg) (mg/L)	Between Groups	0.000	2	0.000	.	.
	Within Groups	0.000	15	0.000		
	Total	0.000	17			
Microbe Total viable count (/100ml)	Between Groups	8536.111	2	4268.056	7.725	0.005
	Within Groups	8287.500	15	552.500		
	Total	16823.611	17			
Escherichia coli count (/100ml)	Between Groups	7.444	2	3.722	2.359	0.129
	Within Groups	23.667	15	1.578		
	Total	31.111	17			

Table 1b: Multiple comparisons by Least Significant Difference (LSD) of River Itare water quality parameters at three sites (Embomos-Itare Forest, Kaptien and Mosore Bridge) in South West Mau, Kenya

Multiple Comparisons							
LSD							
Dependent Variable	(I) Site	(J) Site	Mean Difference I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Boundary	Upper Boundary
pH	Embomos-Itare Forest	Kaptien	0.01167	0.10274	0.911	-0.2073	0.2307
		Mosore Bridge	-0.12333	0.10274	0.249	-0.3423	0.0957
	Kaptien	Embomos-Itare Forest	-0.01167	0.10274	0.911	-0.2307	0.2073
		Mosore Bridge	-0.13500	0.10274	0.209	-0.3540	0.0840
	Mosore Bridge	Embomos-Itare Forest	0.12333	0.10274	0.249	-0.0957	0.3423
		Kaptien	0.13500	0.10274	0.209	-0.0840	0.3540
Turbidity	Embomos-Itare Forest	Kaptien	-0.88167	0.62646	0.180	-2.2169	0.4536
		Mosore Bridge	-10.44167*	0.62646	0.000	-11.7769	-9.1064
	Kaptien	Embomos-Itare Forest	0.88167	0.62646	0.180	-0.4536	2.2169
		Mosore Bridge	-9.56000*	0.62646	0.000	-10.8953	-8.2247
	Mosore Bridge	Embomos-Itare Forest	10.44167*	0.62646	0.000	9.1064	11.7769
		Kaptien	9.56000*	0.62646	0.000	8.2247	10.8953
Dissolved Oxygen (DO) (mg/L)	Embomos-Itare Forest	Kaptien	-0.35333	0.51363	0.502	-1.4481	0.7415
		Mosore Bridge	1.06333	0.51363	0.056	-0.0315	2.1581
	Kaptien	Embomos-Itare Forest	0.35333	0.51363	0.502	-0.7415	1.4481

		Mosore Bridge	1.41667*	0.51363	0.015	0.3219	2.5115
	Mosore Bridge	Embomos-Itare Forest	-1.06333	0.51363	0.056	-2.1581	0.0315
		Kaptien	-1.41667*	0.51363	0.015	-2.5115	-0.3219
Nitrates (NO3) (mg/L)	Embomos-Itare Forest	Kaptien	0.68000*	0.18371	0.002	0.2884	1.0716
		Mosore Bridge	-0.19667	0.18371	0.301	-0.5882	0.1949
	Kaptien	Embomos-Itare Forest	-0.68000*	0.18371	0.002	-1.0716	-0.2884
		Mosore Bridge	-0.87667*	0.18371	0.000	-1.2682	-0.4851
	Mosore Bridge	Embomos-Itare Forest	0.19667	0.18371	0.301	-0.1949	0.5882
		Kaptien	0.87667*	0.18371	0.000	0.4851	1.2682
Nitrites (NO2) (mg/L)	Embomos-Itare Forest	Kaptien	0.000333	0.000873	0.708	-0.00153	0.00220
		Mosore Bridge	-0.001167	0.000873	0.202	-0.00303	0.00070
	Kaptien	Embomos-Itare Forest	-0.000333	0.000873	0.708	-0.00220	0.00153
		Mosore Bridge	-0.001500	0.000873	0.106	-0.00336	0.00036
	Mosore Bridge	Embomos-Itare Forest	0.001167	0.000873	0.202	-0.00070	0.00303
		Kaptien	0.001500	0.000873	0.106	-0.00036	0.00336
Iron (Fe) (mg/L)	Embomos-Itare Forest	Kaptien	-0.02000	0.85704	0.982	-1.8467	1.8067
		Mosore Bridge	-2.74167*	0.85704	0.006	-4.5684	-0.9149
	Kaptien	Embomos-Itare Forest	0.02000	0.85704	0.982	-1.8067	1.8467
		Mosore Bridge	-2.72167*	0.85704	0.006	-4.5484	-0.8949
	Mosore Bridge	Embomos-Itare Forest	2.74167*	0.85704	0.006	0.9149	4.5684
		Kaptien	2.72167*	0.85704	0.006	0.8949	4.5484
Microbe Total viable count (/100ml)	Embomos-Itare Forest	Kaptien	42.500*	13.571	0.007	13.57	71.43
		Mosore Bridge	-6.667	13.571	0.630	-35.59	22.26
	Kaptien	Embomos-Itare Forest	-42.500*	13.571	0.007	-71.43	-13.57
		Mosore Bridge	-49.167*	13.571	0.003	-78.09	-20.24
	Mosore Bridge	Embomos-Itare Forest	6.667	13.571	0.630	-22.26	35.59
		Kaptien	49.167*	13.571	0.003	20.24	78.09
E. coli count (/100ml)	Embomos-Itare Forest	Kaptien	0.333	0.725	0.652	-1.21	1.88
		Mosore Bridge	-1.167	0.725	0.129	-2.71	0.38
	Kaptien	Embomos-Itare Forest	-0.333	0.725	0.652	-1.88	1.21
		Mosore Bridge	-1.500	0.725	0.056	-3.05	0.05
	Mosore Bridge	Embomos-Itare Forest	1.167	0.725	0.129	-0.38	2.71
		Kaptien	1.500	0.725	0.056	-0.05	3.05
*. The mean difference is significant at the 0.05 level.							

IV. Conclusion

Itare riverbank at the downstream site (Mosore Bridge) is slightly degraded and unstable due to intense land use activities and watering of cattle in the river Both natural and planted forests of varied acreage are managed by farmers along river Itare with 62% of the farmers having planted forests and 38% of them having portions of natural forests within their own land. Three tree species were the most preferred (60%) for planting on farms bordering the river, and these were *Eucalyptus saligna* (22%), *Grevillea robusta* (21%) and *Croton spp* (17%).

Although most of the water quality parameters were within the KEBS and WHO limits, there was a decrease water quality downstream particularly in terms of *E. coli* counts and turbidity. Water pH at the three sites ranged from 7.10 to 7.11); Turbidity significantly increased downstream from 4.23 at Embomos-Itare Forest site to 14.67 at Mosore Bridge site; Dissolved oxygen (DO) level at the three sites was significantly lower downstream, where it was 4.55 mg/L at Mosore Bridge; Nitrate (NO_3^-) concentrations at the three sites were lower than Kebs limit of 10 mg/L. Hence, water from the river is safe for drinking with respect to nitrate concentration, which was lowest at Kaptien (0.74 mg/L). Nitrite (NO_2^-) concentrations at the three sites (0.004 mg/L at Embomos-Itare Forest, 0.004 mg/L at Kaptien and 0.005 mg/L at Mosore Bridge) were also lower than Kebs limit of 0.1mg/L. Concentration of heavy metals in the river water was lower than recommended KEBS and WHO limits (Embomos-Itare Forest (0.12 mg/L), Kaptien (0.14 mg/L), and Mosore Bridge (2.86 mg/L)) and the water contained trace quantities (mg/L) of copper (Cu), Lead (Pb) and Mercury (Hg). Water from the river at the upstream and midstream sections is, therefore, safe for drinking. This study recommends public campaign for riparian zone protection and ecologically sound anthropogenic waste management downstream of River Itare.

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