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Diversity and Distribution Patterns of Tree Species along Enkare Narok River, Kenya

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Abstract— The Enkare Narok River system features in the list of the majority of significant streams for conservation of riparian plant biodiversity but anthropogenic activities potentially threaten the formative ecosystem processes. This research paper ascertains the diversity and distribution patterns of riparian tree species in relation to the human disturbances. The procedure for collecting vegetation data involved the use of the line transects method. Transects were laid running orthogonal to the river at 20 m intervals downstream and ten plots in every transect were systematically determined, with a separation distance of 10 meters. A floristic exploration of dominant riparian tree species was done at 51 sites along a 2,250-meter stretch along Enkare Narok River from upper Narok Prisons area to lower Polung'a, in February 2018 towards the end of the dry season. A total of 198 tree species in 12 families were recorded in the Enkare Narok River system with an observed 1.4463-2.4849 Shannon diversity index and which followed a significantly diminutive trend downstream.

Keywords— Riparian, communities, species, river, diversity, habitat, disturbance

I. INTRODUCTION

The Enkare Narok River is located near Narok town. Anthropogenic activities like waste disposal near or into the Enkare Narok River has affected tree diversity and distribution. Farms established have encouraged riparian and wetland vegetation clearance in addition to settlements establishment and harvesting of trees near the riverbank. These anthropogenic disturbances have affected plant species composition and degrades riparian ecosystem. Less attention has been paid to the impacts of the disturbances on riparian vegetation communities and the plant species distribution pattern downstream in the Enkare Narok River system. This paper aims at providing insight into the effects of anthropogenic disturbances on Enkare Narok River riparian vegetation. The objective of the study was to determine the diversity and distribution of tree species along an Enkare Narok River.

The river runs from the elevated northern part of the county and flows directly southwards aided by a gradual slope and later curves towards southwest after passing Narok town. The river has no significant tributaries within Narok County except for water coverages by rocks and unstable earth. Results revealed that altitudinal variations had an impact on the prevalence of natural riparian tree species, their composition and the conditions of natural habitats. Nevertheless, the geomorphology of the upstream segment shows that steep slopes exist similar to some of those found at the midstream sample portion of the riparian site. With a 70 m average width and rocky unstable infertile soil, the upstream riparian zone only supports a small number of native tree species which include *Acacia xanthophloea, Euphorbia candelabrum,* and *Cussonia spicata.* The slope then decreases downstream from the area near Narok Prisons, a condition that makes the landscape to receive deeper gullies which increase the effective water flow. The downstream riparian area is narrow, with the largest percentage covered with a range of small, free rock pebbles to very large rocks deeply embedded into the ground. Some portions of the ground are almost naked with up to 95% of the land having no vegetation. Most of the present vegetation, including shrubs and grass, are dominant on the left riparian zones along the direction of flow of the river water. However, the midstream harbors a number of species with the habitat being maintained by saturations of the soil water. Seasonal flooding characterizes the bank catchments as these banks very narrow on average. Some of the species inhabiting the midstream riparian zone include *Euphorbia candelabrum, Acacia xanthophloea, Brachilaena nerifolia* and *Jacaranda mimosifolia.* Some of these species are young and grow to replace those that have already died in community succession and habitat restoration processes. Others grow together with some degree of growth suppression and habitat colonization. The trees are evenly distributed over the riparian area and most of them are barely over fifteen meters apart. Polung'a area has less stable banks due to decreased rocky outcrops and the river is relatively flattened along this area. However, the rocky characteristic river surface continues to manifest along much of the length of the river. There are comparatively fewer anthropogenic disturbances in the 60-m wide riparian margin but some livestock grazing activities has

been noted. Especially during dry periods, the amount of water declines substantially and this can be attributes to the less human economic activities around Polung'a in relation to the river water and the riparian area. Also the narrower riparian margin poses insecurity to cultivation of crops near the river as domestic and wild animals are likely to invade the plantations easily. A very poor riparian tree species abundance and distribution was observed around Polung'a. Only twenty-four tree species were recorded along a 450-m length of the river segment. The majority of the species were exclusively growing further from the river banks. Only a few shrub types successfully inhabited the extreme riverine regions, with an admirable vigor in their growth. Dominant species within the downstream end of the river stretch include *Warbugia ugandensis* and *Acacia xanthophloea* among other few species. The species are very scarcely distributed and grow without much relatedness to the impacts of the river water on the soil conditions.

Riparian zones form the interface of land and aquatic ecosystems and they are vital in managing nutrient and energy flow between aquatic and terrestrial ecosystems. Although they might occupy comparatively small landscape zones, riparian areas provide substantial contribution to the biodiversity and ecology in the places where they exist [1]. Riparian areas are very vulnerable to the influence of disturbances such as invasion of weed, fire, feral animals and human activities [2]. Most tree species that are depended upon habitat conditions have broadly been used to indicate the conditions prevalent in many riparian systems. The basis of this idea is the supposition that diversity of plant varieties among communities in the overall vegetation cover is closely related to the conditions a habitat possesses [3, 4]. The composition and distribution of plant communities that grow along river systems changes due to pervasive effects of intensity of livestock grazing and vegetation clearance for cultivation. Irrational human activities have a high potential to impact riparian vegetation, and cause degradation of riparian habitats [5].

Land-use effects change on the composition of riparian vegetation considerably varies [6]. The impacts differ from those experienced in terrestrial habitats since they are propagated lower down the river from the interrupted area [7]. The purpose of this paper is to give insight into the impacts of anthropogenic interruptions on riparian tree cover along Narok River ecosystem. The aim was to determine tree biodiversity by the length of a riparian corridor as well as the distribution patterns of tree species to land utilization regime. Rest of the paper is organized as follows, Section I contains the introduction of Enkare Narok River is located near Narok town , Section II contain the related work of studying riparian trees of rivers in East Africa, Section III contain location of the study area, related ecological characteristics and sampling procedures, Section IV contain the results and discussion on diversity and distribution pattern of tree species along the river, section V contains conclusions and future scope of the subject matter.

II. RELATED WORK

This study on the riparian trees of the Enkare Narok River system joins the ongoing studies conducted in riparian environments of East African Rivers. Limited information has affected the documentation of riparian plant ecology in most river systems.

III. METHODOLOGY

The Enkare Narok River is located near Narok town. The river runs from the elevated northern part of the county and flows directly southwards aided by a gradual slope and later curves towards southwest after passing Narok town. The river has no significant tributaries within Narok County except for water coverages by rocks and unstable earth. The research was selected as a stretch of a section of the river comprising three segments: one was located 100 meters from Narok prisons, which formed the upper stream (Figure 1); the midstream segment was established starting nearer to the Catholic nun's residence (**Error! Reference source not found.**); and the last segment was the lowermost area of Polung'a (Figure 1). All sample segments were 450 meters in length and were separated by 450 meters from the point of the first transect of each of the portions.

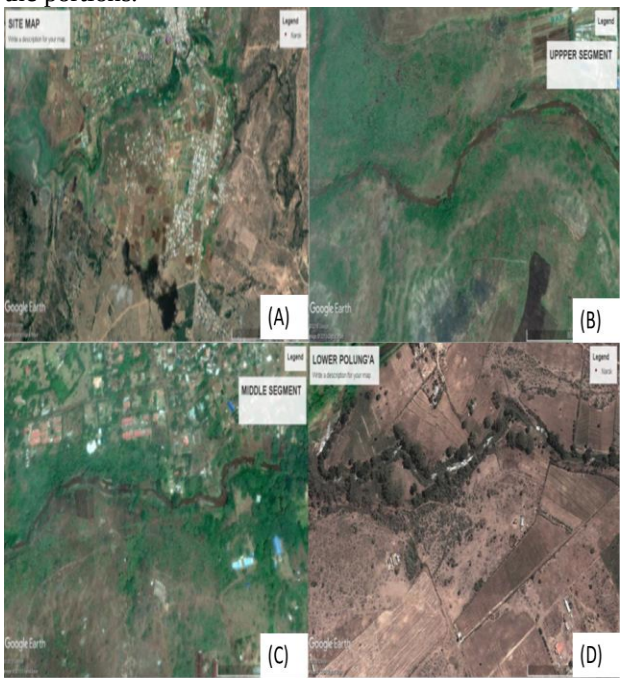

Figure 1: Site map showing the meandering Enkare Narok River on the foreground (A), Upper sampling site near Narok County Prisons (B), Middle segmented located near catholic nun's residence (C) and lower Polung'a sampling site.

1) Riparian vegetation sampling procedure

A reconnaissance general view of the riparian area was initially conducted to note the tree community varieties, without failing to appreciate the degree of anthropogenic

influence in the Enkare Narok River. Three sampling sites described as Narok Prisons area, Catholic Nuns Residence area and Lowermost Polung'a area were chosen for the purpose of this research. These local sites represented a natural ecological system with interplay of all abiotic and biotic factors. The sites also portrayed human disturbance gradient ranging from fairly stable natural plant varieties without major disturbances to greatly disturbed places.

During the study 100-foot tape measure, 1-meter rule and long strings were used to determine linear distances. Wooden pegs were used to anchor transect ropes and red flags to mark points along them. A total of ten 70-m long alternate transects were laid orthogonal to the river and separated by a distance of 50 meters downstream. Transects were placed from the bank to east to west directions because the stream flows from the north to south and later towards southwest. Five alternating plots were systematically established along each transect in the opposite riparian zones with a separation distance of 5 meters (Figure 2).

Along the midstream portion some points were greatly disturbed with permanent buildings close to the river and could not be sufficiently sampled (Figure 3).

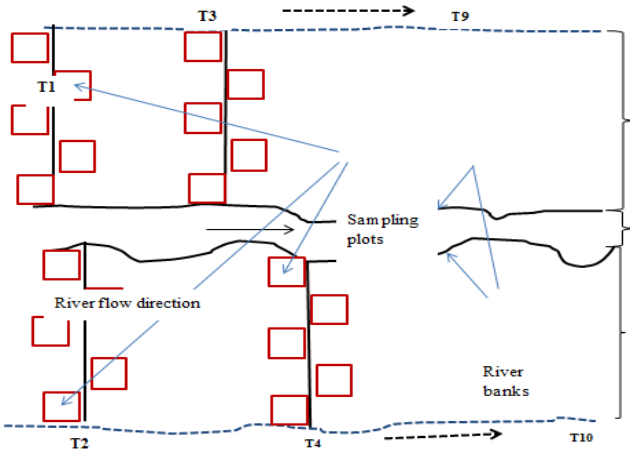

Figure 2: Transect establishment along a segment

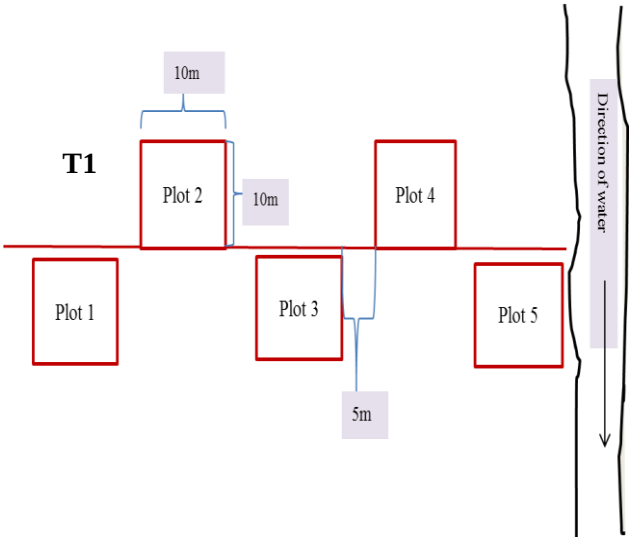

Figure 3: Transect layout

2) Assessment of human influence on riparian data

The degree of anthropogenic disturbance emanating from erosion, cultivation, grazing intensity and plant harvesting was estimated on a scale of six points (**Table 1)**. A 0 zero scale represented stable plots that were no disturbed while a 5 on the scale represented intensively disturbed points [8].

Table 2*:* Scale for assessing anthropogenic influence on riparian vegetation

Scale	Percent (%) estimated degree of disturbance
0	0
1	0-20
2	21-40
3	41-60
4	61-80
5	81-100

This assessment was semi-qualitative and the percentage vegetation cover was used to scale the disturbance levels in affected plots, and the estimation of each type of disturbance was evaluated autonomously from the others.

3) Tree Species Diversity and Evenness

Diversity of species along the riparian area was calculated using Shannon's species diversity index (H) as explained by Shannon and Weaner, using the equation below [9].

$$H' = -\sum_{i-1}^{S} Pi \ln Pi$$

Where S= the total number of all different species recorded, *pi*= Total count of individual species of type *i*/the number of recorded species and ln= Natural logarithm to a base *e*

Species Evenness

Species was calculated as follows [10].

Species Evenness = H/Hmax and, **Hmax= ln (N)**

Where;

Hmax= the possible maximum diversity and

N= number of the plant species observed at a site.

IV. RESULTS AND DISCUSSION

Diversity of tree species observed along Enkare Narok River

A total of 198 tree species in 12 families/ subfamilies were put to record from all the sampled in the Enkare Narok River (Table 2). The trees families that had the highest species diversity included Euphorbia (62 species), Acacia (50 species), Myrtaceae (19 species), Araliaceae (15 species), Ebenaceae (15 species) and Asteraceae (9 species).

Table 3: List of identified and recorded plant species

S.no	Family	Genus	Species Name	Common Name
1	Euphorbiaceae	*Euphorbia*	*Euphorbia candelabrum*	Candelabra tree
2	Fabaceae	*Acacia*	*Acacia xanthophloea*	Fever tree
3	Araliaceae	*Cussonia*	*Cussonia spicata*	Cabbage tree
4	Canellaceae	*Warbugia*	*Warbugia ugandensis*	Pepper bark tree
5	Bignoniaceae	*Jacaranda*	*Jacaranda mimosifolia*	Jacaranda
6	Combretaceae	*Combretum*	*Combretum zeyheri*	Bushwillow
7	Asteraceae	*Brachylaena*	*Brachylaena neriifolia*	Water Witels
8	Meliaceae	*Turraea*	*Turraea robusta*	Honeysuckle tree
9	Anacardiaceae	*Schinus*	*Schinus molle*	Pepper tree
10	Myrtaceae	*Syzygium*	*Syzygium cordatum*	Water berry
11	Ebenaceae	*Euclea*	*Euclea natalensis*	Hairy guarri
12	Apocynaceae	*Tabernaemontana*	*Tabernaemontana stapfiana*	Soccerball fruit

Tree Species Diversity and Evenness Calculations

The diversity of trees ranged between 1.4462-2.4849 and species evenness was 0.582 and showed a declining trend from midstream towards the lower stream. Species The plant diversity index in Enkare Narok River system has a wider range 1.4463-2.4849 than the standard expected range of about ± 0.2 for a richly diversified community [11]. The implication here is that moderate human disturbance and good habitat conditions exist in some river portions while extreme states exist in others. In more ecological terms, the interaction of a number of biotic and abiotic factors have contributed to the observed diversity and distribution pattern of tree species along Enkare Narok river system. However, comparing the upper stream and the middle stream sections the diversity of species differs only slightly with the uppers stream diversity being less while the midstream registering a slightly higher value. This could still be as a result of human activities within these sections since the better roads leading to these areas facilitate transfer of quarry products, majorly concrete stones, and some farm produce.

Table 5: Shannon diversity index and evenness determination for the combined riparian zone

Evenness=1.4463/2.4849 =0.582

S.no	SPECIES	N	*pi*	ln*pi*	*pi**ln*pi*	H
1	*Cussonia spicata*	15	0.044248	-3.1179	-0.138	1.4463
2	*Euphorbia candelabrum*	62	0.182891	-1.6989	-0.3107	
3	*Combretum zeyheri*	5	0.014749	-4.2166	-0.0622	
4	*Schinus molle*	5	0.014749	-4.2166	-0.0622	
5	*Euclea natalensis*	15	0.044248	-3.1179	-0.138	
6	*Tabernaemontana stapfiana*	6	0.017699	-4.0342	-0.0714	
7	*Brachylaena neriifolia*	9	0.026549	-3.6288	-0.0963	
8	*Jacaranda mimosifolia*	4	0.011799	-4.4397	-0.0524	
9	*Acacia xanthophloea*	50	0.147493	-1.914	-0.2823	
10	*Turraea robusta*	6	0.017699	-4.0342	-0.0714	
11	*Synzygium cordatum*	19	0.056047	-2.8816	-0.1615	
12	*Warbugia ugandensis*	2	0.0059	-5.1329	-0.0303	
		198			-1.44635	

The importance of seed dispersal and the vast distribution of *Acacia xanthophloea* along the river system starting from upstream locality downstream depicts that this species type has an assisted mechanism of dispersal aided by water current and can regenerate in riparian zones. The dispersion of *Euphorbia candelabrum* in the upper and middle section shows its tolerance to disturbances and fluctuations in environmental conditions. *Cussonia spicata, Syzygium cordatum, Euclea natalensis, Brachilaena nerifolia* species were found at both sections of the river at varied numbers with *Euclea natalensis* dominating the lower portions of the river. This shows that these species are not very susceptible to disturbances and harsh environmental conditions, and can be seen to have some degree of invasiveness. *Turraea robusta, Shinus molle, Combretum zeyheri* and *Jacaranda mimosifolia* grew in less numbers along the river with only four species of *Jacaranda mimosifolia* living in the middle stream. Soil conditions and disturbance seemed to cause this trend. Warbugia ugandensis was exclusively found in the lower stream with good growing status. *Tabernaemontana stapfiana* showed a tendency to grow better in the upper diversity and evenness at lower Polung'a was very low possibly due to anthropogenic disturbances in the river banks and on the riparian area (**Table 4**).

stream than the middle and lower sections perhaps because of moderate disruptions from human activities.

Table 6: Upstream species diversity index

S.no	SPECIES	N	pi	lnpi	pi*lnpi	H
1	*Cussonia spicata*	10	0.06944	-2.6672	-0.1852	1.2622
2	*Euphorbia candelabrum*	33	0.22917	-1.4733	-0.3376	
3	*Combretum zeyheri*	0	0	0	0	
4	*Schinus molle*	1	0.00694	-4.9698	-0.0345	
5	*Euclea natalensis*	0	0	0	0	
6	*Tabernaemontana stapfiana*	4	0.02778	-3.5835	-0.0995	
7	*Brachylaena neriifolia*	1	0.00694	-4.9698	-0.0345	
8	*Jacaranda mimosifolia*	2	0.01389	-4.2767	-0.0594	
9	*Acacia xanthophloea*	16	0.11111	-2.1972	-0.2441	
10	*Turraea robusta*	0	0	0	0	
11	*Synzygium cordatum*	19	0.13194	-2.0254	-0.2672	
12	*Warbugia ugandensis*	0	0	0	0	
		86			**-1.2622**	

Riparian tree species possess unique adaptations to extend the floatation of their seeds. Nevertheless, distinct variations still occur among species where some seeds can only bear floatation span of a few hours while others remain stable for months before they geminate. Riparian vegetation acts as a buffer for sediments and nutriments delivered by agricultural runoff, provides stability to stream banks and confers shade thus reducing evaporation leading to moderated stream temperature conditions [12]. This lends credence to the fewer disturbed riparian areas at Catholic nurses' estates, where stable banks and suitable moist habitats supports more diversified plant species. Since organic matter from riparian plants provides energy for riverine and wetland areas, the progressing human influence replaces the tree varieties and reduces the potential energy that Enkare Narok River system possesses.

Evenness of species

Variations in the use of land in Enkare Narok river system is likely to have contributed to the differences in riparian tree species diversity. Anthropogenic disturbance affects the diversity of macrophytes in riparian ecosystems [13]. The potential human disturbances in the Enkare Narok River system to mention cultivation, grazing, erosion and harvesting of plant species in riparian areas can be intelligibly interpreted as the key control factors of the local diversity patterns. Cultivation, exploitation and grazing were the main predictors of an alteration in evenness and diversity whereas erosion was considered to be a result of a merger of the three variable factors.

Tree species evenness and diversity along the riparian area increased downstream from the upper sampling site, the area around the Narok Prisons, to the middle sampling site where the trend began to decline. The middle study site, the area near the residence of the catholic nuns, registered the highest value of species evenness and diversity while the lowermost Polung'a area showed the least value of all. The major possible reason for this tendency may be ascribed to the higher water levels along the middle segment resulting from suppression of stream discharge by Narok Water treatment center.

Table 7: Midstream species diversity index and evenness (E=1.2622/2.079=0.607)

S.no	SPECIES	N	pi	lnpi	pi*lnpi	H
1	*Cussonia spicata*	5	0.02924	-3.5322	-0.1033	1.2821
2	*Euphorbia candelabrum*	24	0.14035	-1.9636	-0.2756	
3	*Combretum zeyheri*	5	0.02924	-3.5322	-0.1033	
4	*Schinus molle*	4	0.02339	-3.7554	-0.0878	
5	*Euclea natalensis*	11	0.06433	-2.7438	-0.1765	
6	*Tabernaemontana stapfiana*	1	0.00585	0	0	
7	*Brachylaena neriifolia*	8	0.04678	-3.0622	-0.1433	
8	*Jacaranda mimosifolia*	2	0.0117	-4.4485	-0.052	
9	*Acacia xanthophloea*	18	0.10526	-2.2513	-0.237	
10	*Turraea robusta*	5	0.02924	-3.5322	-0.1033	
11	*Synzygiuum cordatum*	0	0	0	0	
12	*Warbugia ugandensis*	0	0	0	0	
		83			-1.28205	

Patterns of natural disturbance in many streams and major rivers have a relation with the positon of the landscape [14]. Anthropogenic disturbance effects vary among areas located in the watershed margins and may occur with unpredictable intensity and timing [15]. The extensiveness

of disturbances of riparian plant covers from cultivation was evidenced from the vast gaps of growing vegetation that registered low species diversity. The Narok Prisons and Polung'a riparian areas had the lowest diversity of tree species recorded, which was primarily due to the cultivation and grazing activities observed. The area around the Catholic sisters' quarters was less degraded, ideally because of the proximity to Narok County authorities who monitor this area since the Narok water supply treatment base is located along this portion of the river and intrusions may be deemed potentially risky.

Table 8: Downstream species diversity index and evenness (E=1.28205/2.3026 =0.556)

S.no	SPECIES	N	pi	lnpi	pi*lnpi	H
1	*Cussonia spicata*	0	0	0	0	0.207
2	*Euphorbia candelabrum*	5	0.20833	-1.5686	-0.3268	
3	*Combretum zeyheri*	0	0	0	0	
4	*Schinus molle*	0	0	0	0	
5	*Euclea natalensis*	4	0.16667	-1.7918	-0.2986	
6	*Tabernaemontana stapfiana*	1	0.04167	0	0	
7	*Brachylaena neriifolia*	0	0	0	0	
8	*Jacaranda mimosifolia*	0	0	0	0	
9	*Acacia xanthophloea*	16	0.66667	-0.4055	-0.2703	
10	*Turraea robusta*	1	0.04167	-3.1781	-0.1324	
11	*Synzygiuum cordatum*	0	0	0	0	
12	*Warbugia ugandensis*	2	0.08333	-2.4849	-0.2071	
		29				

Estimated Anthropogenic Influence based on observed data

There were nineteen disturbed plots out of the total fifty in the upper stream with varying forms of disturbance. There were eleven and twenty-three disturbed plots in the middle and lower stream sites respectively. Forms of disturbances were the same throughout the sampled river stretch. This data translates to 38%, 22% and 46% levels of disturbance in upper, middle and lower sampling sites respectively.

V. CONCLUSION AND FUTURE SCOPE

The determination of tree diversity on riparian area in the Enkare Narok River system is among the few studies that have been conducted in some East African rivers to characterize riparian zones and communities as well as to emphasize the need to conserve riparian ecosystems. The variation in the diversity and distribution of tree species among the sampled sites is mainly due to the differences in the conditions of habitats that anthropogenic disturbances have caused in the Enkare Narok River system. However, it would be unsatisfactory to conclude that this variation in diversity of species will always be same along riparian zones. Extremely extensive chance occurrences may cause drastic drifts in the form and the structural functions of riparian zones. In such a case, the determination of distribution patterns of tree communities can only satisfy the hypothesis when a study is done after full succession and recovery of the affected zones. Sometimes it might be challenging to quantify variables concerning riparian community. We can think of this in the observation that along the riparian zones some points are dangerous to access yet they may have exclusive features and species diversity of great interest. In such cases, only estimates, or near-value results are likely to be observed. With specific reference to Enkare Narok River system, implicit exotic species are only concentrated near homes or guarded areas and carrying out comprehensive palatable research on the tree varieties needs some legal procedures. The local community has been vert exploitative on the introduced trees in an attempt to acquire timber and light wood for construction and fuel purposes respectively. With the rate of quarrying and riparian plant replacement by Narok natives and their neighbors, the long-term potential outcomes would predispose the Narok community to hardships of monumental proportions.

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