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Implication of vegetation removal on coarse particulate organic matter (CPOM) in Chepkoo River, Kenya

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ABSTRACT

Clearing forests at catchment levels is known to affect the rivers' ability to provide vital ecological functions such as coarse particulate organic matter (CPOM) input as well as maintenance of water quality. This study was carried between April and June 2017 at Chepkoo River, in Elgeyo-Marakwet County to establish the effect of vegetation clearance on coarse particulate organic matter and riparian vegetation composition and diversity at three sites differing in extent of canopy cover (upstream-0-35%; midstream-0-5% and downstream- 0-10%). The study involved vegetation identification along selected transects of 50 by 30 meters and CPOM collection on both banks of the river as well as in the stream channel using a quadrat of effective sampling area = 0.29 m^2. Sixteen (16) plant species were observed at the upstream site compared to the midstream site that had 13, and 9 for the downstream site. Shrubs dominated the right orographic bank in the upstream and downstream sites whilst forbs dominated the left orographic bank in the upstream and midstream sites respectively. Variations in vegetation diversity were observed with the upstream site recording a higher number (2.2), compared to the downstream (1.9), and midstream sites (1.7). The quantity of CPOM (pooled data from the banks) collected among the sites differed significantly ($F_{(2, 24)}$ = 12.3; p < 0.001) with the midstream site having the highest amount (Tukey HSD, p < 0.05). The mean difference of CPOM retention within the stream channel was statistically significant ($F_{(2, 24)}$ = 8.05 p<0.001) with the upstream site recording the highest amount. This study confirms that reduced canopy cover can lead to a reduction in in-stream CPOM in lotic systems. Replanting of riparian vegetation at clear-cut sites along river corridors can serve as a management strategy for tropical rivers to enhance water and habitat quality.

Key words: Lotic systems, Organic matter, Forest degradation, Vegetation diversity, Water Quality

Introduction

Rivers in forested regions depend on allochthonous organic matter inputs for their energy budgets (Wallace *et al.,* 1997). Riparian vegetation are vital in providing various ecosystem services including reducing floods and soil erosion (Goebel *et al*.,2003). Without the riparian vegetation, rivers will be deprived of coarse particulate organic matter (CPOM), since they are the largest contributors of these materials in aquatic systems (Simanonok *et al.,* 2011). According to Anderson and Rosemond, (2010), the highest percentages of energy flow in the food webs originate from CPOM.

CPOM is indicative of both functional and structural component of the stream and it has a great influence on the channel morphology and processes, for example, nutrient dynamics and retention of fine sediment (Diez *et al*.,2000; Gomi *et*

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al.,2002, Webb and Erkrine 2003b; Quin *et al*., 2007). Clear-cut of the forest near the rivers results in decreased CPOM stored in the river because of a reduction of inputs from the allochthonous material (Burrows *et al*., *2014*). CPOM standing stocks can be altered through the dynamics of the hydrological regime (Davis *et al*., 2005). Therefore, when a clear cut is undertaken near the stream, it leads to increase in the CPOM exported and thus the CPOM stored in the stream decline tremendously.

Across the world, riparian corridors are under threat, and currently they are heavily cleared to pave way for agriculture and animal husbandry among other anthropogenic activities (Dudgeon 2000). The observed trend of use of riparian zones particularly along the banks of the rivers will greatly affect the ecosystem and ecological service (Gopal *et al.* 2002). The intense clearances of riparian corridors have resulted to variation of vegetation composition, diversity and productivity (Smakhtin and Anputhas 2006). In addition to alteration of the community structure, removal of riparian vegetation may contribute to stream pollution (Bere andMangadze 2014) and loss of biodiversity (Sultana *et al*. 2014). Chepkoo River has been facing the threat of removal of riparian vegetation and thus the study aimed at assessing how it has affected on the amount of CPOM in the river.

Materials and methods

Study Area and the study site
Location of study area and topography

The study was carried out in Chepkoo River, in Keiyo South, Elgeyo-Marakwet County (Fig. 1)

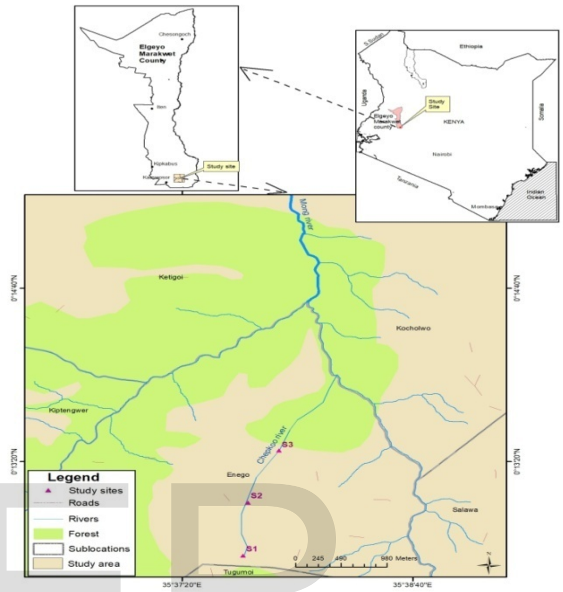

Figure 1: Map of Kenya showing study sites (Source: topographical map of Kenya, 2014)

Tumoo forest, which is bordering Chepkoo River is located in Elgeyo- Marakwet County, Keiyo south Sub County at latitude 0˚12' 17", 0˚15'28" North, longitude 35˚36' 19", 35˚39'17" East, with an average elevation of 2,347 meters. Keiyo South Sub County is divided into three topographical zones, which run parallel to each other; the highland "Tengunin", escarpment "Mosop" and lowland "soin". Tumoo forest is located within the forested escarpment and the highland region, which is part of Kerio catchment area. The altitude of the highlands rises up to an altitude of between 2300 to 2700 meters above the sea level. When viewed from highland the valley provides a magnificent scenery (Ng'ang'a, 2006). The great range of altitude brings considerable variability in climatic and physical conditions (Ng'ang'a, 2006).Rivers in this region run parallel to the escarpment, in the south-Northern direction. It is within this escarpment that Chepkoo River finds its tributaries.

Climatic conditions and Vegetation

In the valley the mean temperatures is estimated to be approximately 26˚C, while in the highland it is estimated to range between 14˚C to 18˚C, but a times it can drop to as low as 6˚C (Kipkore, *et al* 2014). There is a considerable variability in rainfall patterns, in which the dry conditions dominate the valley and in highland areas, there is a high rainfall. Erosion is severe at the isolated spots on the steep slopes bordering the valley. The main vegetation types in Tumoo Forest consist of mountain bamboo mainly *Arundinaria alpina*, *K. Schum*, African pencil cedar (Juniperusprocera Hochstetter ex Endlicher 1847) and climbing trees among many other tree species (Kipkore, *et al* 2014).

Physical parameters of the studied sites

The physical and chemical characteristics of the three study sites are presented in Table 1. The lowest temperature was recorded at the upstream site while the highest was recorded at the downstream site.The midstream site recorded the highest conductivity value, of 107.14±5.663µs/s. The downstream site recorded oxygen concentration values of 7.26±0.212 mg/L while the midstream site recorded the highest value of 0.111 ±0.007 mg/Lin terms of TSS. Discharge increased from upstream to downstream.

Table1: The physical variables measured in Chepkoo River (values are means ± standard error except for pH that is given as ranges, Temp-temperature, vel-velocity, Dis-discharge).

Parameters	Upstream	Midstream	Downstream
Temp(°C)	19.089 ± 0.196	22.86±0.720	22.90±0.631
Cond (µs/s)	91.211 ± 8.046	107.14±5.663	97.54±11.212
DO (mg/L)	7.20 ±0.240	7.23±0.231	7.26±0.212
TSS (mg/L)	0.102±0.005	0.111 ±0.007	0.104±0.006
pH	7.29-8.19	7.18-8.31	7.29-8.25
Vel (m/s)	0.562 ±0.038	0.858±0.076	0.710±0.060
Dis(m^3/s)	0.138±0.049	0.710±0.392	1.446±0.586

Demographic profile

In the last few decades, area around Tumoo Forest has experienced high growth rates of both people and livestock. The residents of this area are the Keiyo community, which are part of the Kalenjin tribe who are residing in Rift Valley. Approximately 20,354 people live within Kocholwo location where Tumoo forest is located (Ng'ang'a, 2006).

Sampling design

Characterization of riparian vegetation

An area measuring 50 x 30 m was delineated at every study site. Vegetation was observed along three transects within the delineated area approximately 25 m apart. Vegetation species composition was noted, counted and recorded every 1m along each transect. This was done on both the right and left banks at each site.

Collection of coarse particulate organic matter (CPOM)

Collection of CPOM commenced at the downstream site, moving upstream within the stream channel to minimize the physical disturbance while sampling. Samples were also collected from both riverbanks at each site. Within the stream channel, three CPOM samples were collected using a quadrat (effective sampling area = 0.29 m^2) thrown at random. This was repeated on the banks to collect a total of six samples three from each bank. The samples were kept in well-labeled polythene bags and transported to the laboratory for further processing.

Determination of vegetation species diversity, similarity and evenness

Vegetation composition, diversity, evenness and similarity indices were determined. Whereby the vegetation diversity was computed using the Shannon-Wiener Index (Shannon, 1963) equation 1.

$H' = \Sigma pi Inpi$………………………… Equation 1

Where,

H'= Shannon wiener index

p_i= proportion of individuals found in species

n= number of individuals in each species

Evenness was determined using Shannon's Equitability index (E_H) equation 2, and similarity index was calculated using Sorensen's coefficient of community (CC) equation 3 (Shannon, 1963).

$E_H = H'/$

ln S.………………………………………Equation 2

Where,

E_H= Shannon's Equitability Index

H'= Shannon-wiener diversity index

S= Total number of species in the community

$CC = 2c/(S_1 + S_2 +$

$S_3)$……………………………………… Equation 3

Where,

C= number of species common in the three study sites

S_1= number of species in the upstream

S_2=number of species in the midstream

S_3= number of species in downstream

In the laboratory, CPOM samples were dried in pre-weighed aluminium cups at 60^0 C for 24 hours, and weighed to obtain the dry weights (DW) estimates. The dry CPOM was then separated into leaves, twigs, barks, fruits and others and their weight determined separately.

Results

Vegetation composition, diversity, evenness and similarity

Vegetation composition

The species list of vegetation observed at Chepkoo River study sites is presented in Table 2. 20 plant species were identified at the three study sites. The upstream site had 16 plant species, and the midstream site had 13, while the downstream site had 9 plant species. The three study sites had 6

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species in common. Some species were restricted to upstream site such as *Arundinaria alpina,Cynodon dactylon, Solanum nigrum* and *Stephania abyssinica while Lantana camara* was present in the midstream site and absent in the other two study sites (Table 2).

Table 2: Presence or absence of different types of vegetation in upstream, midstream and downstream (+ means present and – means absent, S = number of species)

PLANT SPECIES	UPSTREAM	MIDSTREAM	DOWNSTREAM
Acacia tortilis	+	+	-
Acanthus eminens	+	+	+
Arundinaria alpine	+	-	-
Caesalpina spinosa	-	+	+
Croton macrostachyus	+	+	+
Croton megalocarpus	-	+	-
Cupressus lusitanica	-	+	+
Cynodon dactylon	+	-	-
Eucalyptus saligna	+	+	-
Ptendium spp.	+	-	+
Lantana camara	-	+	-
Olea welwischii	+	-	-
Oplismenus burmannii	+	+	+
Pandanus kirkii	+	-	-
Pennisetum clandestinum	+	+	+
Plectranthus spp.	+	+	-
Sadge	+	+	+
Solanum nigrum	+	-	-
Stephania abyssinica	+		-
Vernonia lasiopus	+	+	+
S	**16**	**13**	**9**

The study sites comprised of five vegetation types namely; trees, shrubs, forbs, grass and climbers. Shrubs dominated the upstream and downstream sites (Fig. 2). In terms of trees, they dominated in the upstream site but were less than 40% of the total. All the five vegetation types were well represented in the upstream site but climbers were missing in the other two sites.

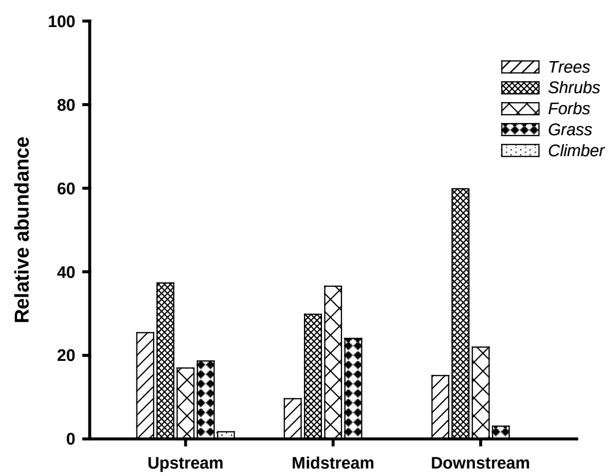

Figure 2: The relative abundance of vegetation types in the three study sites of Chepkoo River

Vegetation diversity, evenness and similarity

The highest diversity was observed at the upstream site, followed by downstream and midstream respectively (Table 3). The downstream site had the highest evenness followed by upstream and lastly midstream. In terms of similarity, 32% of the species were similar in the three sites as indicated by the Sorensen's coefficient of similarity (Table 3).

Table 3: Vegetation diversity, evenness and similarity at the three sites along Chepkoo River

Sampling site	Shannon index (H')	Equitability index (E)	Sorensen's coefficient
Upstream	2.1513	0.7759	0.32
Midstream	1.6769	0.6993	
Downstream	1.9388	0.8824	

CPOM on the banksand in the stream channel of Chepkoo River

CPOM on the banks

The quantity of CPOM (pooled data) collected in the midstream site dominated the other two sites as depicted in Figure 3. The difference in mean organic matter quantities collected among the three sites was statistically very highly significant ($F_{(2, 24)} = 12.427$, $p < 0.001$). Significantly, low amounts of CPOM were recorded at the downstream site (Tukey HSD < 0.05).

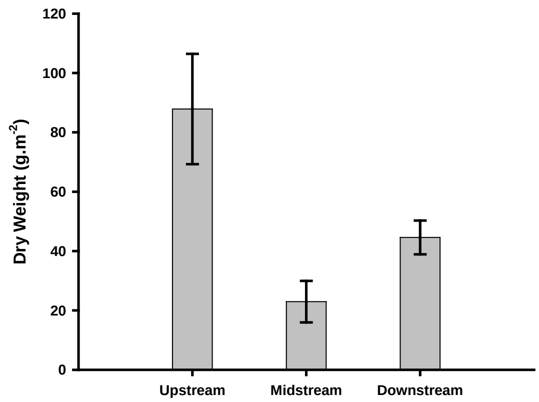

Figure 3: Total CPOM dry weight (pooled) collected on the banks at the three sites

CPOM in the stream channel

The quantity of CPOM retained in the stream channel in the three sites is presented in Figure 4. The upstream site had the highest followed by the downstream and the least was at the midstream site. The mean difference in the amount of CPOM among the three sites was statistically significant (One-Way ANOVA, $F_{(2, 24)} = 8.053$, $p<0.001$). The upstream site differed significantly with the other two sites (Tukey HSD, HSD, $p<0.05$).

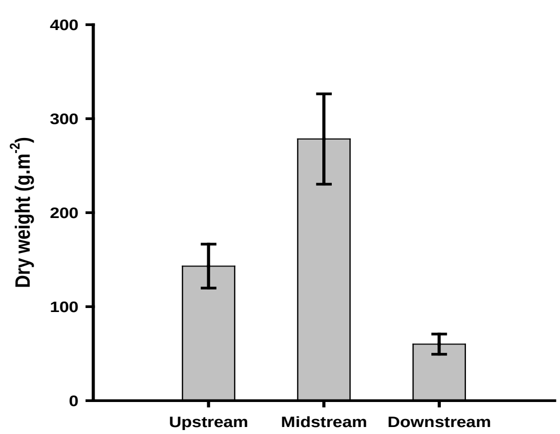

Figure 4: The dry weight of CPOM (g/m^2) in river channel along the three study sites of Chepkoo River.

Discussion

Vegetation composition along Chepkoo River

Riparian vegetation is selective as to where it establishes, because its sensitive to changes in flooding frequency and duration as well as soil type of the region. Vegetation composition ismuch influenced by the overbank deposition of soil and debris materials. Many authors have established that a slight change in elevation either for a few centimeters or for meters can lead to an alteration in vegetation diversity and species evenness (Sagar *et al*., 2003; Pamela *et al*., 2008; Sunil *et al*., 2012). The use of riparian zone for agricultural purposes has been an ancient activity and it brings interference on the ecosystem services and the riparian ecology (Gopat *et al*., 2002; Michael *et al*., 2009). Furthermore, riparian disturbances have resulted to loss of biodiversity (Sultana, 2014) and stream pollution (Bere and Mangadze, 2014).

Vegetation composition along Chepkoo River depend on the anthropogenic activities practicedalong the river banks. Banks that were farmed had different species composition in comparison to those that were graced. The upstream site recorded the highest number of species as compared to the other two sites. The increased agricultural activities in the midstream and the downstream might have caused the variation in vegetation composition. According to Smakhtin and Anputhas (2006), the intense use of riparian zones for farming activities have caused variation in the native species composition, richness and productivity. Notably, the shrubs and forbs were dominating the midstream and downstream sites, which is an indication that the disturbances along the riparian zone of Chepkoo River might be the cause of variation in the native species composition. In addition, there was low vegetation species similarity among the three sites, which can be associated with high disturbance of riparian corridors. This was in support of a study undertaken by Michael, *et al*., (2009), who found that in Sonora riparian ecosystem the disturbed site had low diversity of vegetation.

Coarse particulate matter on the banks and in the stream channel

Coarse particulate organic matter (CPOM) is vital for forested streams as they support the food web. Furthermore, they provide habitat and food for microbes in the river. Therefore, the recorded difference in CPOM quantities from the three sites of Chepkoo River is of great interest in determining the stream health. The quantity of CPOM is an important factor used to assess the effect of anthropogenic changes to the stream ecosystem (Masese, 2015).

It was observed that the banks of midstream site had the highest amount of CPOM despite the region being less vegetated. The observation can be attributed to the transportation of CPOM from other regions and deposited in the midstream site. It is worth noting that the left bank had a gentle topography and hence a likelihood of stream overflowing, and the CPOM retained. The site also had wood debris and rocks that were deposited on the banks and thus the materials intercepted the transported CPOM. However, the downstream site had less CPOM and this could be attributed to less vegetation in the area and the gentle topography, as well as few riverbank materials that could intercept the CPOM.

When the river channel was considered the collected CPOM was significantly different among the three sites. It was evident that the upstream site had the highest amount of CPOM collected than the other two sites. CPOM transportation is normally determined by the discharge and other retentive structures within the channel (Morara *et al*., 2003). Therefore, since the upstream site had low discharge than the other two sites, then CPOM was likely to be retained for a long period than the other sites. In addition, other factors like the gentle gradient, river channel roughness could be responsible for the observed significant difference. CPOM responds to quick flow rate and since the midstream site had a high discharge, hence the low retained CPOM in the site. However, there was a higher retention of CPOM in downstream site than the midstream site, and it can be attributed to the topography of the site. The downstream site had a gentle gradient, coupled with the size and type of the CPOM transported leading to a high amount of collected CPOM in the site. A difference in the type and frequency of retentive structures is likely to result to differences in CPOM retention on stream channels (Mathooko, *et al.,* 2001a & b). The quantity of CPOM retained on the banks was about 3 times higher than that observed in the stream channel.

Conclusions

This study confirms that reduced canopy cover lead to reduced in-stream CPOM along Chepkoo River. Furthermore, the considerable amount of CPOM recorded in the banks as compared to the in stream is an indication of the banks being a good storage and processing region of CPOM. The anthropogenic activities along the riparian corridors of Chepkoo River have brought vegetation diversity reduction along the three study sites. Therefore, replanting of riparian vegetation at clear-cut sites along river corridors can serve as a management strategy for tropical rivers.

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