Effect of Land Use on Leaf Litter Decomposition in Upper Mara Streams, Kenya

Tsisiche A., M'merimba C. M. and Mbaka J. G.
Biological Sciences Department, Egerton University
P. O. Box 536 – 20115 Egerton
Email: audreytsisiche@gmail.com

Received	Reviewed	Accepted	Published
26th Nov. 2016	9th Sept. 2016	18th Nov. 2017	18th Jan. 2018

Abstract

Modification of riparian vegetation via land use change alters leaf litter processing rates in streams. This study aimed at investigating the effect of land use change from forestry to agriculture on leaf litter decomposition in the upper Mara River catchment, Kenya. The study involved collecting, drying and weighing leaves of Eucalyptus saligna (exotic) and Macrocalyx neubotonia (native). About 6g of each leaf species was enclosed in litter bags measuring 11 x 11cm and mesh size of 10mm. The bags were exposed randomly in six streams; three draining agricultural and three draining indigenous forests. They were later retrieved at intervals of 0, 1,3,7,14,28 and 48 days, dried and weighed. The difference in processing rates of Eucalyptus leaves were statistically not significant (insert test and statistics) between streams draining indigenous forest (mean -k = 0.039±0.009, pooled data) and streams draining agricultural areas decaying Macrocalyx leaves were –k = 0.095±0.005 in streams draining agricultural areas and k=0.062±0.01 for streams draining indigenous forest. The two values differed significantly ($t = 2.892$, d.f=4, $p= < 0.05$). Significant differences in processing rates were also evident between Eucalyptus and Macrocalyx leaves in streams draining indigenous and agricultural forests respectively (ttest, $p<0.05$). It would take 63 and 69 days for 90% of leaves of Eucalyptus to be processed in agricultural and forested streams respectively whilst Macrocalyx leaves would take 24 and 53 days. Processing rates for the two leaves were generally higher in agricultural streams than in forested streams most probably due to higher nutrients especially Phosphate concentration arising from agricultural land. In all the study streams SRP had significant correlation with decay rates for both species. Significant differences in processing rates observed between the two leave species could be attributed to differences in leave toughness and the presence of inhibitory compounds in eucalypts. The findings of this study suggest that land use change interacts with change in the composition of riparian tree species to influence decomposition rates of leaf litter in streams. This has implications on the

functional organization of shredders and nutrient cycling in streams. This study confirms that land use activity has an effect on litter decomposition rates in Upper Mara catchment streams. However Eucalyptus decomposition did not respond to change in land use activity because of its poor quality which masks the land use effect.

Key words: Leaf litter, land use, Exotic, native, Processing rate, Mara River

Introduction

Allochthnous leaf litter breakdown is a fundamental process for the understanding of stream ecosystems and their functioning (Wallace and Webster, 1996). The process is greatly influenced by the stream watershed charecteristics. There is a a strong connection between streams and their watershed through movemment of water and material (Allan, 2004). Anthropogenic activites in the watershed like deforestation for agriculture, settlemnent and pastrure directly affect stream physical and chemical charecteristics (Acuña *et al.*, 2013). Riparians zones play a vital role of buffering the stream against these effetcs. The riparian zone also controls water temperature and light availability. For headwatwe streams, the riparian zone is the base of the food web in terms of leaf litter input for shredders and gatherers (Sweeney *et al.*, 2004).

When riparian vegetation is altered through land use change, the terestialaquatic linkagein terms of organic matter and nutrient inputs is saverley altered. Riparian vegetation removal can change the trophic status of the stream from heterotrophic to autotrophic, resulting in a complte shift in stream ecosyetem functioning (Ferrera *et al.*, 2012). Apart from riparian reduction, replacement of native riparian forest with secondary exotic vegetation such as Eucalyptus has been found to change the quality and quantity of litter input into the streams with resultant influences on the composition of aquatic communities (Masese *et al.*, 2014).

In the Mara River basin, Kenya, indigenous riparian vegetation along agricultural streams is being replaced by exotic species such as Eucalyptus and Gravillia (KFS, 2009). The extensive replacement is because the rapid growth and wide applicability of Eucalyptus species for wood and other uses purposes (Majer and Recher, 1999). This replacement together with agricultural activities can sharply alter the characteristic of the decomposition process hence affecting the entire stream energy flow (Graça *et al.*, 2002). With these changes, there is a need to understand the effect of land use change and replacement of indigenous tree species along riparian areas with exotic tree species whose leaf quality and litter input regimes might be different from the riparian tree species they are replacing. The aim of this study was to investigate the effect of replacing one of the most common riparian tree species along riparian areas of most streams with an exotic tree species that is widespread and yet its effects on organic matter processing in streams is not well understood.

Material and Methods

Study Area

This study was conducted in mid-altitude (1900-2300m a.s.l) first order streams draining western slope of Mau Escarpment within Kenyan Rift Valley. Six streams were chosen within Nyangores sub-catchment which is a tributary of Mara River. Mara River drains the Mau Forest Complex (MFC) and flows into Lake Victoria. The forest is the source of most of the rivers flowing into lakes Baringo, Nakuru and Victoria.

Mau forest has adversely been affected by human encroachment. The forest has been cleared for human settlement, exotic tree plantations and tea plantations, both small and large scale (Lovet and Wasser, 1993). Despite the encroachment, there are relatively intact forests blocks within protected areas. People living in the neighborhood of the forests are involved in farming tea, food crops (maize, beans and potatoes) and animal keeping. The farming activities have resulted in the loss of indigenous riparian vegetation along streams (Minaya *et al.*, 2013). Native trees such as Macrocalyx are being replaced with Eucalyptus which is thought to have a high economic value.

Land use was categorized using a combined digital elevation model remote sensing images (Landsats Thematic Mapper data of 2008, 30m resolution) and topography map (1-50,000) Survey of Kenya 1971. The area of each land use type for each sub-catchment draining to a sampling site (point) was calculated and presented as percentage. Sites were selected in one of two catchment-scale land uses that were defined as: (a) forest sites (n = 3) draining catchments with >60% forest; (b) agriculture sites (n = 3) draining catchments with >60% agriculture. The streams were chosen based on accessibility, discharge and physical habitat conditions as shown in Figure 1.

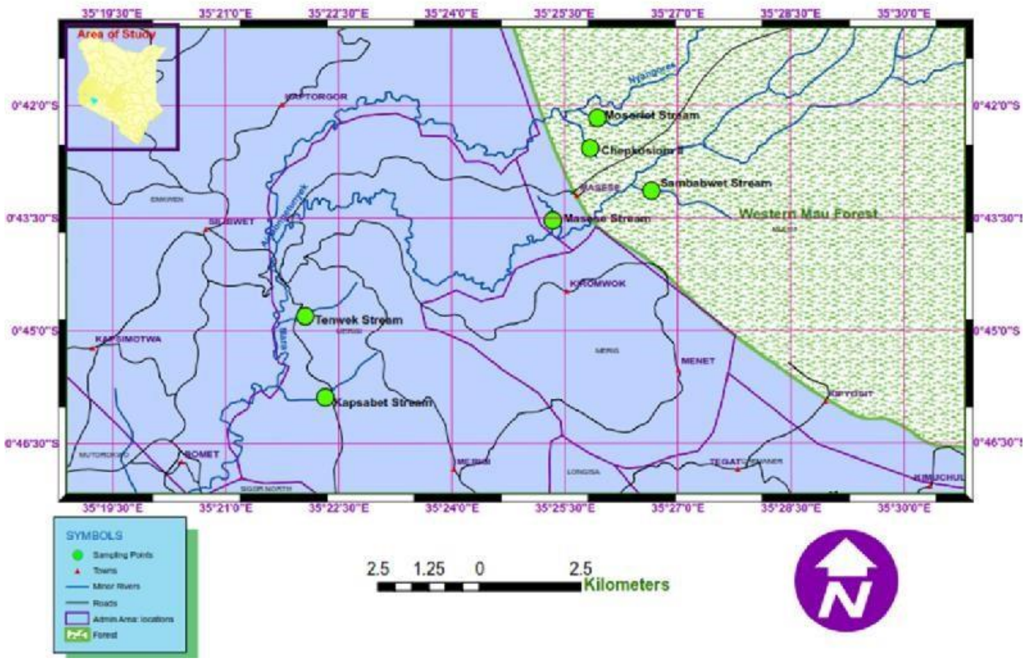

Figure 1: A map showing the samplings streams in Nyangores sub catchment

Physico-chemical Variables

This study was conducted between May 2013 and July 2013, which was mainly towards the end of a wet season. Water physico-chemical parameters, including pH, temperature, and conductivity and dissolved oxygen (DO) were measured in situ with probes during each sampling session. HACH HQ 40d probe was used to measure DO and temperature while HACH ECO 40 probe was used to determine pH and conductivity. Triplicate readings were taken during each sampling time.

Water samples were collected in triplicate for nutrient analysis using 500ml acid washed HDEP bottles from the thalweg in each stream during deployments and retrieval dates of litterbags. To avoid the influence of water disturbance, the samples were collected before deployment or retrieval of litterbags. The water samples were then transported to the laboratory analysis in a cooler at 4ºC, for nutrients analyses within 24 hours.

Leaf-litter Breakdown Experiments

The study involved collecting, drying and weighing leaves of Eucalyptus saligna (exotic) and Macrocalyx neubotonia (native). About 6g of each leaf species was enclosed in 288 litterbags measuring 11 x 11cm and mesh size of

10mm. Before deployment the 288 litterbags were arranged in set of 3 replicates per plant species(two species) per stream(6 streams) per number of retrieval times(8 retrieval times).The bags were deployed randomly in six streams; three draining agricultural and three draining indigenous forests. They were retrieved in triplicate at intervals of 0, 1, 3, 7, 14, 28 and 48 days, dried and weighed.

Ammonium-Nitrogen (NH_4-N), Nitrate Nitrogen (NO_3-N) and NitriteNitrogen (NO_2-N) were analyzed using standard methods according to APHA (2004) method. The NH_4-N was determined by sodium salicylate method. NO_3-N was determined using sodium-salicylate method, while NO_2-N was analyzed through the reaction between sulfanilamid and NNaphthyl-(1) ethylendiamin-dihydrochlorid. Soluble reactive phosphorus (SRP) was analyzed using the ascorbic acid method (APHA, 2004). Total phosphorus (TP) was determined through persulphate digestion of unfiltered water to reduce the forms of phosphorus present into SRP. Total Suspended Solids (TSS) was estimated gravimetrically by filtering a known volume of water samples through pre-weighed Whatman GF/C filters of pore size 0.45µm (reference).

Leaf-Litter Decomposition Rates

In the lab, leaves were carefully cleaned off extraneous material with tap water in 250µm mesh size sieve, then dried at 60^0c for 48h and reweighed. The invertebrates retained on the sieve were preserved in 10% formalin for later identification to family level and counting. Macroinvertebrates were identified in the lab and grouped into their functional feeding groups according to Masese *et al.*, 2014. The leaves were then ashed in the furnace, and ash-free dry mass (AFDM) determined according to (Benfield, 1996). The AFDM weights were for all retrieval dates were used to determine decomposition rates by fitting an exponential model (Equation 1) to determine breakdown rate constant (-k).

$$DM_t = DM_0 e^{-kt} \qquad 1$$

Where DM_t is the dry mass (g) remaining at time t (days), DM_0 is the initial dry mass, e is the natural logarithm and k is the breakdown rate constant.

This was done after natural log transformations of the dry mass (DM) at the beginning and at the end of each exposure duration according to the procedure by Graca *et al*., (2005) as follows:

$$-k = (\ln DM_o - \ln DM_t) / t \qquad 2$$

The data was then fitted to the linear model (Cuffney and Wallace, 1987) by regression $\log_e$ percentages of the remaining dry mass (%RDM) on time to do the calculation of the required time for 50, 80, and 90% of the leaves to be processed in all the streams.

$$y=b+ax \qquad 3$$

Where y is the %RDM and x being the number of days, b the slope and a, is the intercept (Peterson and Communis 1974). To determine the effect of land use on breakdown rates ki/kr (i for impacted (agriculture) and r for reference (forested) stream respectively was calculated (Gessner and Chauvet, 2002).

Data Analysis

The data collected was tested for significant differences using one way ANOVA, Correlation and T-test as the test statistics in sigma plot 11 software. The effect of land use on decomposition rates was tested by repeated T test with land use as the control variable and decomposition rate as the response variable over time. The ki/kr coefficients (i for impacted [agriculture] and r for reference [forest] streams, respectively) were calculated for Eucalyptus-and Macrocalyx litterbags (Gessner and Chauvet, 2002) to determine the effect of land use on leaf litter breakdown. The score was given following Gessner and Chauvet (2002): 2, ratio = 0.75–1.33; 1, ratio = 0.50–0.75 or 1.33–2.00; 0, ratio = <0.50 or >2.00. Whereby the scores are interpreted as follows: 0, severely compromised stream functioning; 1, compromised stream functioning; 2, no clear evidence of impaired stream functions.

Results

Land Use

Forested sites had a mean (±SD) value of 95.3 ± 13.4% of total catchment area under forestry with other land uses (grasslands, shrub land) comprising <10% (Table 1). All forested sites did not have any proportion of agricultural land use. Agricultural sites had a mean (±SD) of 93.8 ± 3.4% of total catchment area under agriculture with the rest of the land uses (roads, bare ground, urban areas) comprising <10% of the land area. All agricultural sites did not have any proportion of forest land use.

Table 1: Mean (±SE) values for different proportions of land uses in the Agriculture and Forest streams in the upper Mara River basin, Kenya; agriculture – n = 3, forest – n = 3.

	Stream type	
Land use	Agricultural	Forested
%Forest	-	95.3±13.4
%Agriculture	93.8±4.2	-
%Other land uses	6.3±4.2	5.8±3.3

Streams Characterization

All the physico-chemical variables measured are presented in Table 2 below. Temperature values in all the sites ranged between 12^0C -20^0C. Mosoriot had the lowest temperature of 12.6^0C while Kapsebet had the highest temperature of 20.40^0C. Agricultural streams had higher temperatures than forested ones. There was significant difference in temperature between forested and agricultural sites. pH ranged between 4-8.6 with Tenwek recording the lowest pH of 4.2. Kapsebet had the highest pH of 8.6. Conductivity on the other hand ranged between 40-107 µS/cm with Kapsebet recording the highest conductivity of 107.1 µS/cm. Generally streams draining agricultural land use had the higher conductivity the than draining forested land use. DO mg/l ranged between 5-7.6 mg/l with Sambambwet recording the highest of 7.62. Kapsebet had the lowest DO of 5.6 mg/l. Forested streams had significantly higher dissolved oxygen (DO) than agricultural streams. TDS ranged between 34-80 mgl/l with agricultural streams recording significantly higher values than forested streams.

Table 2: Mean (± SE) and ranges values for physicochemical characteristics of the study streams. Values with the same superscript letter are not significantly different (Tukey's *post hoc* test)

Variable	Chepkosiom	Mosoriot	Sambambwet	Masese	Tenwek	Kapsebet
Temp (0^0c)	12.8±0.3[a]	12. 6±0.3[a]	13.0±0.4[a]	16.7±0.7[e]	19.7±0.4[b]	20.4±0.4[b]
Cond. (µS/cm)	45.3±2.5[c]	40.4±1.1[c]	47.9±2.7[dc]	73.8±6.2[bc]	107.1±4.6[db]	88.7±3.2[b]
pH	6.0-4.00	6.1-6.0	6.1-5.9	8.6-8.0	7.6-7.4	4.2-5.0
DO (mg/l)	7.5±0.1[a]	7.6±0.1[a]	7.6±0.2[a]	6.6±0.1[ab]	5.8±0.3[b]	5.6±0.3[b]
DO (%)	77.3±3.2[a]	77.6±3.3[a]	78.0±3.8[a]	71.1±3.3[ab]	58.7±3.6[b]	59.4±2.6[b]
TDS (mg/l)	34.9±0.8[ad]	36.2±0.9[d]	36.5±2.5[d]	65.0±2.8[e]	72.9±2.7[be]	80.8±2.5b

Nitrogen and Phosphorous Concentration in the Study Streams

Tenwek had the highest concentration of nitrates of 10.2mg/l while Masese had the lowest of 4.85mg/l. Mosoriot had the lowest Nitrite concentration of 3.716 µg/l while highest concentration µg/l of 15.83 was recorded in

Kapsebet. SRP concentration ranged between 2-13 µg/l with Agricultural stream recording higher concentrations. Masese had the highest concentration of 13.4 µg/l while Mosoriot had the lowest of 2.9 µg/l. Highest levels of TP were also recorded in Agricultural streams with Masese having the highest of 13.4 µg/l . Like all the forested streams Mosoriot had the lowest TP concentration of 3.9 µg/l. Agricultural streams had the highest levels with Kapsebet recording the highest as shown in table 3. TSS was also highest in agricultural streams as opposed to forested streams with Masese recording the highest level of 106.8 mg/l. The average of nitrogen and phosphorous concentration during the entire study period are presented in Table 3.

Table 3: Mean (±SE) Nitrate, Nitrate, Soluble reactive phosphorous, Total phosphate and TSS levels in the study streams

Variable	Chepkosiom	Mosoriot	Sambambwet	Tenwek	Masese	Kapsebet
No_2(µg/l)	4.4±2.0	3.7±1.0	3.87±2.0	9.8±3.9	13.4±4.67	16.0±4.4
No_3(mg/l)	6.1±4.5	6.4±2.2	5.8±2.4	10.2±3.6	4.8±2.2	9.6±3.2
TP(µg/l)	4.3±2.4	3.9±1.7	5.8±7.3	3.3±0.0	13.4±7.4	5.1±0.7
SRP (µg/l)	4.3±2.0	2.7±1.5	2.2±4.3	2.6±1.6	13.10±7.9	2.3±3.6
NH_3(µg/l)	13.7±4.3	8.4±3.8	3.5±1.2	9.0±4.4	17.7±2.8	11.3±5.2
TSS (µg/l)	30.6±3.5	32.3±4.4	36.5±4.6	57±13.6	106.8±23.4	98.9±24.7

Litter Processing Rates

There was a negative correlation between percentage dry mass remaining and exposure time for both species regardless of the land use as shown in Figure 2.

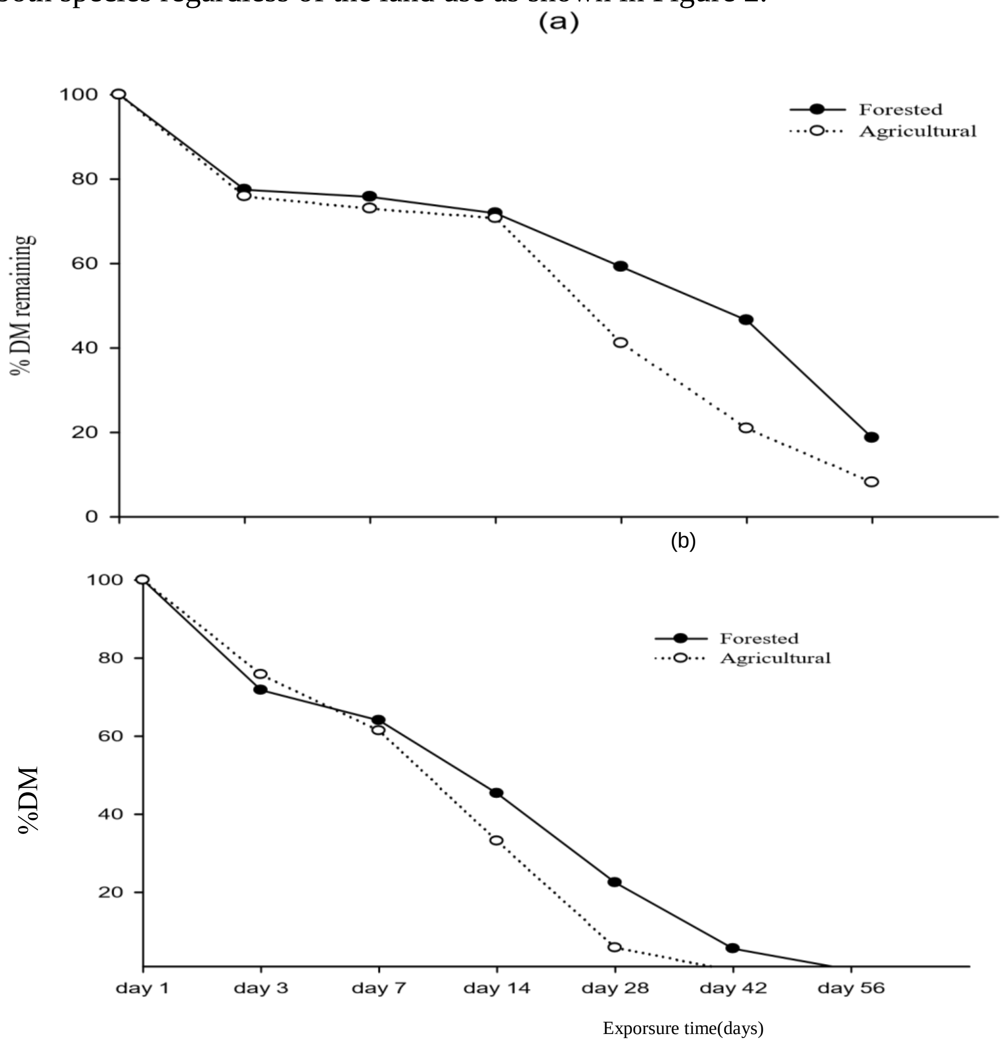

Figure 2: Remaining dry mass (percentage) for the Eucalyptus (a) and Neubotania (b) leaves in streams draining forested and agricultural land uses during the incubation period

Eucalyptus decay rates ranged from 0.01 to 0.04 across agricultural and forested streams. The difference in processing rates of Eucalyptus leaves were statistically not significant between streams draining indigenous forest (-k = 0.039±0.009, pooled data) and streams draining agricultural areas (-k = 0.045±0.009) (t = 0.404, d.f=143, p >0.05). Processing rates (pooled data) for Macrocalyx leaves were –k = 0.095±0.005 in streams draining agricultural areas and –k =0.062±0.01 for streams draining indigenous forest. The two values differed significantly (t = 2.892, d.f=143, p= < 0.05). Figure 3 shows how the decay rates for both species differed with land use. Significant differences in processing rates were also evident between Eucalyptus and Neubotania leaves in streams draining indigenous and agricultural forests respectively (t-test, p<0.05).

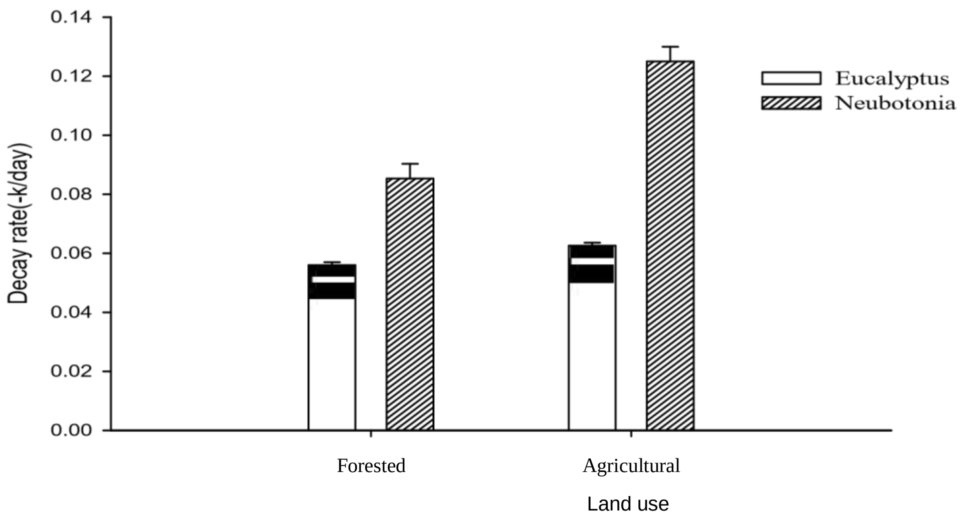

Figure 3. Effect of Forested and Agricultural land use on the decay rates of Eucalyptus and Neubotonia tree species

The ki/kr coefficient for Neubotania and Eucalyptus was 1.545 and 1.135 respectively. It would take 63 and 69 days for 90% of leaves of Eucalyptus to be processed in agricultural and forested streams respectively whilst Neubotania leaves would take 24 and 53 days as shown in Table 4.

Table 4: Time required in days for 25%, 50%, 75% and 90% of each species to decompose in all the study streams. Euc-*Eucalyptus* while Mac*Macrocalyx*

Study stream	**25%**		**50%**		**75%**		**90%**	
Tree species	***Euc***	***Mac***	***Euc***	***Mac***	***Euc***	***Mac***	***Euc***	***Mac***
Forested streams								
Mosoriot	7. 8	1.4	22.6	17.2	47.3	44.2	80.4	79.8
Chepkosiom	1.4	2.9	11.8	11.2	29.5	25.5	53.0	44.3
Sambambwet	9.2	2.2	22.4	8.6	44.8	19.6	74.4	34.1
Agricultural streams								
Masese	5.3	2.0	18.7	7.2	41.5	14.4	71.7	23.9
Tenwek	5.4	2.8	13.3	7.5	26.7	15.6	44.5	26.3
Kapsebet	6.2	2.3	19.8	6.2	42.6	12.9	73.6	21.7

Based on Pearson correlation, there was significant positive correlation between the decay rates and temperature on Mosoriot, Sambambwet. Masese and Tenewek (r=0.94.0.84 and 0.91 respectively). Conductivity had positive correlation with decay rates in Sambambwet, Masese, Kapsebet and Tenwek (r=0.90.0.89.0.93 and 0.92 respectively). SRP had a significant co-relation with decay rates in all the study streams as shown in Table 5.

Table 5: Pearson correlation coefficients between decay rate and physicochemical variables. The values with superscript have significant correlation

	Forested streams	**Agricultural streams**

	Mosoriot	Chepkosiom	Sambambwet	Masese	Kapsebet	Tenwek
Temperature	0.94*	-0.51	0.85*	-0.90*	-0.61	-0.91*
Conductivity	0.41	0.40	0.91*	0.90*	0.93*	0.93*
DO	-0.26	0.31	-0.60	0.11	0.22	0.29
TP	0.15	0.67	0.88*	0.58	0.48	0.29
SRP	0.77*	0.90*	0.9*	0.77*	0.82*	0.85*
NO_3	0.29	0.33	0.34	0.18	0.04	0.11
NO_2	0.69	0.67	-0.59	-0.26	0.77	-0.70
NH_3	-0.14	-0.76	0.78	0.22	0.08	-0.58

Alpha<0.05

The macroinvertebrate colonization of the liter bags was found to be diverse, with all functional feeding groups (e.g., collectors, predators, scrapers, grazers, etc.), and all major taxa (e.g., Ephemeroptera, Plecoptera, Trichoptera, Diptera, etc.) represented in our field collections. Baetidae (75.94%) and chironomid (10.36%) dominated in the litter bags retrieved from forested streams. Likewise the two groups also dominated in the litterbags obtained from forested streams (Baetidae-15.32, chironomidae52.06%). Agricultural stream recorded higher macroinvertebrates, with 4640 individuals while the rest belonged to forested streams as shown in Figure 4. Neubotonia litterbags had higher individuals than Eucalyptus litter bags in all the study streams except in Masese. The identified macroinvertebrates belonged to 6 orders and 23 families.

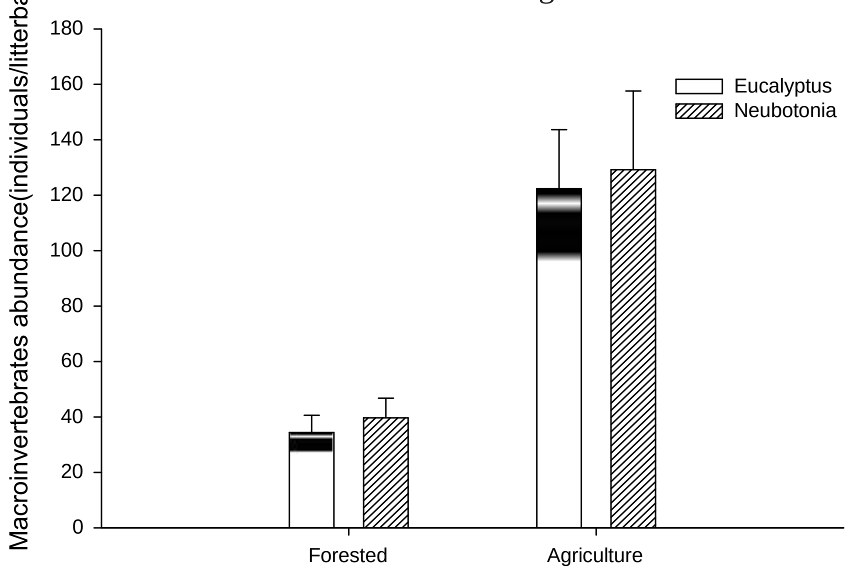

Figure 4: Effect of Forested and agricultural land use on Mean (±SE) for macroinvertebrates abundance (individuals per bag) for Eucalyptus and Neubotonia species litter bags

Filter feeders and gatherers dominated in forested and agricultural streams respectively. Shredder abundance was slightly higher in forested sites (about 13% of the total individuals collected) than agricultural sites (about 4% of total individuals collected). Scrappers were the least in agricultural sites with 1% while predators were the least in forested sites with 3%.

Discussion

Human activities along riparian corridors have resulted in the replacement of natural forest with exotic trees species such as Eucalyptus. This has changed both biotic and abiotic characteristics within the streams and rivers. Agricultural activities within the riparian zones of upper Mara streams has resulted to reduction in canopy cover, nutrient loading, and turbidity increased temperatures. In this study it was evidenced that land use has compromised litter decomposition especially with respect to Neubotonia species .Native tree species Neubotonia are being replaced with exotic species like Eucalyptus. Unlike most native species Eucalyptus is of poor quality hence not preferred by shredders. Results from a studies done by Palmer and Filoso, 2009; Acuña et al., 2013 on effect of land use on stream functioning agrees with what was found in this study. The studies showed that changes typically reduce habitat complexity and biodiversity and affect organic matter dynamics, nutrient cycling, water purification and erosion processes. Another study also done by Masese et al., 2014 in the upper Mara catchment had similar results. In the study, they found out that human activities within the Mara catchment have strongly affected leaf litter decomposition and the overall stream ecosystem functioning such as litter decomposition.

The high decomposition rates recorded in agricultural streams is attributed to the water quality of the streams which have been altered due to the increased human activities (Mathurai and Chauvet, 2002). High temperature and nutrient levels in these streams promote the growth and metabolic activity of aquatic hyphomycetes and shredders (Rosemond et al., 2002). Human activities can affect stream biota and ecosystem functioning directly through increased nutrient concentration or indirectly through oxygen depletion. Of major concern in streams are non-point sources of inorganic nitrogen and phosphorus resulting from agriculture runoff (Carpenter et al., 1998). Apart from water quality, differences in stream physical characteristics have potential to influence the mechanical fragmentation of leaves. Although Eucalyptus decomposition rates did not differ with land use, it would take more days to decompose in forested streams than Agricultural streams. However the lack of significance difference can be explained by the fact that Eucalyptus poor leaf quality affect decay rate more than land use effect. Eucalyptus affects the Aquatic community due to their poor quality (Graca et al., 2002). The low undergrowth diversity associated with Eucalyptus plantations, coupled with the antibiotic properties of its oils could interfere microbial decomposition and shredders activity (Murphy and Giller 2000). The leaves have poor food resources for the stream detrivores hence affecting the detrivores food chain and the entire stream ecosystem food web (Larranaga et al., 2006).

On the other hand Neubotania would take almost twice the numbers of days to decompose in forested streams than agricultural streams. These can be explained by the differences in the physico-chemical parameters and nutrient levels of the streams. High temperatures in agricultural streams stimulates physiological activities of microbial community and shredders hence increased decomposition rates (Bergfur and Friberg 2012). Apart from temperature agricultural streams had slightly higher nutrient concentration which also increased decay rates (Suberkropp et al., 2010, Grattan & Suberkropp, 2001). The Ki/kr of both species were above 1 this implies that agricultural land use has compromised the decay rates of both species.

Macroinvertebrate colonization increased with time due to the conditioning of the leaves by microbial community. This makes the leaves more palatable hence attracting shredders (Moreti et al., 2007). A possible explanation for the similar macroinvertebrate colonization, on both tree species may be the availability of alternate food sources and habitat within leaf packs.

The fact that relative abundance of shredder invertebrates was very low, while collector gatherers was more can be explained by the fact that, leafbags acted more as a FPOM retention structure for collectors rather than a direct source of CPOM for shredders (Hoffmann, 2005). Some studies have demonstrated the low/limited attractiveness of artificial leaf bags for shredders. Cortes et al. (1997) found no differences in the relative abundance of shredders in leaf-bags and in the streambed and argued that when there is an abundant supply of high quality food in the stream, there is no reason for shredder aggregation in leaf-bags.

Conclusion

In the study, it is evidenced that human land use activities have an influence on stream ecosystem functioning. Streams under agricultural land use in Mara catchment are exposed to activities such as agriculture, logging, human settlement and grazing. These activities have resulted to degradation of the streams through river bank erosion and increased nutrient run off into the streams. The activities in turn compromise leaf litter decay. Replacement of native trees species with exotic species such as Eucalyptus has adversely affected the in stream leaf litter processing in the Mara catchment. Planting of Eucalyptus species in the riparian zones has resulted to input of poor quality leaves into the stream. The leaves are less preferred by shredders due to their poor quality hence reduced food resources for the shredders community Canhoto et al., (2002). If unchecked, riparian and watershed deforestation together with replacement of native tree species will shift the functioning of these streams with food webs becoming more reliant on autochthonous resource and microbial processing of leaf litter, which cannot support diverse consumers and complex food webs in the entire Mara basin.

Acknowledgement

We would like to acknowledge the financial support provided by GLOWSWater Scholars and Florida University. We also express our sincere gratitude to Egerton university Biological Sciences department for provision of laboratory and all the required equipment.

References

Acuña, V., Díez, J. R., Flores, L., Meleason, M., and Elosegi, A. (2013). Does it make economic sense to restore rivers for their ecosystem services? *Journal of Applied Ecolology*: 10:1365-2664.

Allan, J. D. (2004). Landscapes and rivers capes: the influence of land use on stream ecosystems. *Annual. Review Ecololgy*. 35: 257–284

American Public Health Association- APHA (2004). Standard methods for the examination of water and wastewater, 21st Ed. Water Pollution Control Federation. Washington, D.C.

Bergfur J, and Friberg N, (2012). Trade-offs between fungal and bacterial respiration along gradients in temperature, nutrients and substrata: experiments with stream derived microbial communities. *Fungal Ecology*, 5:46-52.

Benfield, E. F., (1996). Comparison of litterfall input to streams: stream organic matter budgets. *Journal of the North American Benthological Society*, 16: 104-108.

Cuffney, T. F. and Wallace, J. B. (1987), Leaf litter processing in Coastal Plain streams and floodplains of southeastern Georgia, U.S.A. *Archive Hydrobiology*, 76:1-24.

Canhoto, C., Bärlocher F. and Graça M. A. S. (2002). The effects of Eucalyptus globules oils on fungal enzymatic activity. *Archive Hydrobiology*, 154: 121-132.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N. and Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, 8: 559–568.

Cortes, R. M. V., Abelho, M. and Rebelo, S. B. (1997). The macroinvertebrate colonization of leaf bags: is there a pattern? *Limnetica* 13: 71–75.

Ferreira V, Elosegi A, Gulis V, Pozo J. and Graça M. A. S. (2006). Eucalyptus plantations affect fungal communities associated with leaflitter decomposition in Iberian streams. *Archiv fur Hydrobiologie*. 166: 467–490.

Filoso, S., (2009). Environmental markets: the power of regulation response.
Science 326, 1061– 1062.

Gessner, M. O. and Chauvet, E. (2002). A case for using litter breakdown to assess functional stream integrity. *Ecological Applications* 12: 498– 510.

Graça, M. A. S., Pozo, J., Canhoto C. and Elosegi A. (2002). Effects of Eucalyptus plantations on detritus, decomposers and detritivores in streams. *The Scientific World*, 2: 1173-1185

Graça, M. A., Bärlocher F. and Gessner M. (2005). *Methods to Study Litter Decomposition: APractical Guide, 37-42.* Dordrecht, the Netherlands: Springer.

Grattan, R.M. I. and Suberkropp, K. (2001). Effects of nutrient enrichment on yellow poplar leaf decomposition and fungal activity in streams. *Journal of the North American Benthological Society*, 20: 33–43.

Kenya Forestry Service (KFS) (2009). A Guide to On-Farm Eucalyptus Growing in Kenya.

Hoffmann, A. (2005). Dynamics of fine particulate organic matter (FPOM) and macroinvertebrates in natural and artificial leaf packs. *Hydrobiologia.* 549:167–178.

Larranga, A., Basaguren, S., Elsogei, A. and Pozo, J. (2006) Assessing the impact of Eucalyptus plantation on benthic macroinvertebrate communities by litter exclusion experiment. International Journal of Limnology, 42:1-8.

Lovett, J. C. and Wasser, S. K., (1993). Biogeography and Ecology of the Rain Forests of Eastern Africa. Cambridge University Press, Cambridge

Majer, J. D. and Recher, H. F., (1999). Are Eucalypts Brazil's friend or foe? An entomological viewpoint. *Anais da Sociedade Entomológica do Brasil*, 28:185-200.

Masese F. O., Kitaka N., Kipkemboi J., Gettel G. M, Irvine K. and McClain M. E. (2014). Litter processing and shredder distribution as indicators of riparian and catchment influences on ecological health of tropical streams. *Ecological Indicators*, 46: 23–37.

Mathuriau, C. and Chauvet, E. (2002). Breakdown of leaf litter in a neotropical stream. *Journal of the North American Benthological Society*, 21: 384–396.

Minaya, V., McClain, M.E., Moog, O., Omengo, F. and Singer, G. (2013). Scale-dependent effects of rural activities on benthic macroinvertebrates and physico-chemical characteristics in headwater streams of the Mara River, Kenya. *Ecological Indicators* 32,116–122

Moretti, M. S., Gonçalves, J. F., Ligeiro, R. and Callisto, M. (2007). Invertebrates colonization on native trees leaves in a neotropical stream (Brazil). *International Review Hydrobiology* 92:199-210.

Murphy, J.F. and Giller, P. S. (2000) Seasonal dynamics of macroinvertebrate assemblages in the benthos and associated with detritus packs in two low-order streams with different riparian vegetation. *Freshwater Biology*, 43: 617–631.

Peterson, R. C., and Cummins, K. W. (1974). Leaf processing in a woodland stream. *Freshwater Biology*, 4: 343-368.

Rosemond, A. D., Pringle, C. M., Ramı´rez, A., Paul, M. J., & Meyer, J. L. (2002). Landscape variation in phosphorus concentration and effects on detritus-based tropical streams. *Limnology and Oceanography*, 47: 278–289.

Sweeney, B. W., Bott, T. L., Jackson, J. K., Kaplan, L. A., Newbold, J. D., Standley, L. J., Hession, W. C. and Horwitz, R. J. (2004) Riparian deforestation, stream narrowing, and loss of stream ecosystem services. Proceedings of the National Academy of Sciences of the United States of America.

Suberkropp, K., Gulis, V., Rosemond, A. D., and Benstead, J. P. (2010). Ecosystem and physiological scales of microbial responses to nutrients in a detritus based stream: Results of a 5 year continuous enrichment. Limnology and Oceanography, 55: 149-155.