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Effect of Land Use on Distribution and Abundance of Ground Dwelling Macroinvertebrates in Kirimiri Forest in Embu County, Kenya

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Abstract: Ground dwelling macro invertebrates are essential for soil functions and other significant ecological process such as nutrient cycling. The distribution and ecological role of crawling macro invertebrates may be influenced by anthropogenic factors. Human factors such as deforestation and agricultural activities that destroy the habitat pose great threat for the survival of macro invertebrates. Most of the natural ecosystems including forests in Kenya have been encroached, segmented and reduced in size by the rapidly growing population. However, studies on the impact of such destructive activities on the abundance and distribution of ground dwelling macro invertebrates are limited. Thus, there exist an information gap on macro invertebrate composition and their distribution in different ecosystem and habitat segments in Kenya. Such studies are necessary in generating knowledge and creating wholesome understanding to facilitate policy making, habitat management and conservation of crawling macro invertebrates. Based on the above highlights, this study was conducted to determine the effect of land use on the distribution and abundance of ground dwelling macro invertebrate in Kirimiri forest in Embu County, Kenya between January and April 2016. The Napier grass plantation, Tea plantation and indigenous intact forest were evaluated for their macro invertebrates. In every habitat studied, crawling macro invertebrates were caught using the pit fall traps set in 50 m by 50 m grid subdivided into six rows at equidistance gap of 8 m. The pit holes comprised of 60 (250 ml capacity) clear plastic containers filled with 30 ml mixture of ethanol and liquid soap. Macro invertebrates were identified using their morphometric features and then stored in 70 % Ethanol for further laboratory identification at the National museums of Kenya headquarter in Nairobi, Kenya. The data collected was log transformed (log10) and analyzed using Scientific Analysis System (SAS) version 9.4 and significance means separated using Least Significance Difference (SLD). The indigenous intact forest recorded the highest mean (6.91) of macro-invertebrates with family of Polydesmidae having a mean of 18.833 being the most abundant. Tea plantation had the second largest mean (5.49) of macro-invertebrates and the family Platydesmidae (14.185) was the most abundant group. Napier grass plantation had a mean of 4.32 and the family Arionidae with a mean of (6.479) was the most abundant group. The data collected was analyzed using Scientific Analysis System (SAS) version 9.4 and significance means separated using Least Significance Difference (SLD). The indigenous intact forest recorded the highest mean of macro invertebrates with family of Polydesmidae being the most abundant (mean=17.33). Tea plantation had the second largest mean (4.59) of macro invertebrates, and the family Gryllidae was the most abundant group with mean of 12.667. Napier grass plantation had a mean of 3.94 and the family Platydesmidae was the most abundant group (mean=12.833). The disparity in abundance and distribution of terrestrial macro invertebrate observed in this study may have resulted from micro climate and microenvironment shift influenced by human activity along and within the forest. Our results provides a baseline information, which is important for future biological monitoring of impacts associated with land use changes in the county.

Keywords: Macro invertebrates, Habitat effect, Kirimiri forest, Embu County, Kenya

I. Introduction

Macro-invertebrates are organisms that are visible by naked eye and lack the spine. Examples of macro- invertebrates include flatworms, crayfish, snails, clams and insects, such as dragonflies [1]. Invertebrates may be grouped as aquatic invertebrates [2] [3], wetland invertebrates [4] or terrestrial macro-invertebrates. These invertebrates are significant component of biodiversity in any ecosystem in terms of functionality [1] [2] [5] [6]. Ecosystem biodiversity loss may compromise important process of communities' such as efficiency in resource acquisition, biomass production, decomposing and nutrient recycling and may cause ecosystem instability [7] [8] [9]. Numerous studies have been done on aquatic macro-invertebrates. Jackson and Reder [2] studied freshwater macro-invertebrates in the United States of America in relation to their frequency, lifespan and ecological significance. Mabid et al. [9] studied the distribution and diversity of the aquatic macro-invertebrates assemblages in semi-arid areas within the Eastern Cape Karoo in South Africa and reported on the macro-invertebrates which included Notonectids, copepods and Gastropod occupying wetlands. Variation in macro-invertebrates was associated with water turbidity, pH and altitude [9]. Other studies on aquatic macro-invertebrates have been reported in Heilongjiang province Northern China [4], Mexico [10], Antarctica [1], Southeast Alaska [12] and Tanzania [2]. In Kenya, Abongo et al. [14] studied aquatic macro-invertebrates in Nyando river catchment areas. Additional studies of macro invertebrates in Kenya have been at Moiben river [15], Mara Basin [16] and in Lake Victoria [17]. Evidently, there exist scanty information on the terrestrial as compared to aquatic macro-invertebrates despite of their ecological significance [18] [19]. Terrestrial crawling macro-invertebrates are very important in the soil functions and to the human life [20]. Nonetheless, hundreds of these organisms are fast becoming extinct worldwide [21] due to knowledge gap that exists on invertebrates [22], habitat wise study of macro-invertebrate aimed at generating knowledge on abundance, evenness and their distribution is necessary. Further, studies on effect of habitat change on distribution of terrestrial macro-invertebrate are fundamental. Significance of enhanced study on macro-invertebrates is justified by rapid habitat loss globally [22]. Habitat loss has been hastened by anthropogenic activities like the real estate development, agricultural practices such as fertilizer and herbicides application and uncontrolled harvesting of forest resources [23]. Habitat destruction goes against expected human responsibility of conserving the biodiversity for efficient ecosystem function [24]. Though the Rio Janeiro 1992 Convention on Biological Diversity require member states such as Kenya to document their fauna and flora to enhance biodiversity conservation [25], most of Kenyan macro-invertebrates have not been documented. The current study was conducted to generate knowledge on the effect of land use on composition, distribution and abundance of macro-invertebrates in Kirimiri forest in Embu County in Kenya. Our data does not build on any previous information of the study area but compares the findings to other studies done elsewhere in the world. We hypothesize that there was no significant difference in the number of macro-invertebrates across Napier grass plantation, Tea plantation and in indigenous forest areas of Kirimiri Forest in Embu County. We expected the forest to exhibit a higher abundance and diversity compared to other areas studied.

II. Methods

Study Area

Kirimiri forest an area of current study, is located in the Mukuuri locality of Runyenjes, Embu County in Kenya (Figure 1). It covers about 800 acres area and it is recognized as an ecologically sensitive site in Africa by International Union for Conservation of Nature as mentioned in Ogolla et al. [26]. There are a variety of rare indigenous and medicinal trees and animals that are threatened by deforestation and disturbance. Its' Centre lies at the latitudes of S 000 25' 22.30" and longitude of E 37o 32' 41.42"and it has an elevation of 5454 feet above sea level at the hilltop. The elevations within the homesteads where Napier grass plantation takes place is at the height of 4939 feet, a longitude of S 00025.640` and a latitude of E 037033.038`. At the edges where the Tea plantations takes place the elevations are at 5038 feet above sea level, a longitude of S 00025.655` and a latitude of E 037033.002`. The predominant languages spoken are Kiembu, Swahili and English. The hill is culturally famous as a hide out for Mau Mau fighters including Embu's most venerated fighter General KubuKubu. The total population of Runyenjes is 142,360. The area receives a bimodal rainfall with two distinct rainy seasons. The long rains (March- June) while short rains in (October-December). Rainfall quantity received varies with altitude averaging from 640 mm and in some areas to as high as 1495 mm per annum. The temperature ranges 120C in July to a maximum of 300C in March with a mean of 210C as mentioned in Ogolla et al. [26]. There are three major types of vegetation around this region: Intact forest, Tea plantations and the Napier grass plantation. The forest appears not to have experienced any fire disasters. The soil in the forest is composed of dead organic matter and thus very soft in nature.

Figure 1: Map of Embu County showing the study site (CGok, 2014)

Sampling Procedure

Sampling was done between January and April 2016. Six parallel line transects separated by 8 m gap were made in a 50 x 50 sampling grid across the study site. Ten pitfall stations were established a long individual transects at equidistance gap of 4.6 m that totaled to 60 pitfalls for every study site and 180 for the whole study. Each pitfall trap consisted of a transparent plastic bowl of diameter 6 cm and 8 cm depth, buried to its' rim in soil and partly filled with a mixture of soap and 30 ml 70 % Ethanol in accordance with Pekár [27]. Ethanol served as a preservative while the soap ensured that the macro invertebrates remained afloat by enhancing surface tension of the preservative. Traps were set at 8 am and checked on the following day at 8 am.

Data Collection

Trapped macro invertebrates were collected by sieving the content of the trap and picking by forceps. The specimen collected were stored in vials containing 70% ethanol preservative and the vial labeled as per the station transect and collection date.

III. Results

Macro-invertebrate Family Abundance in Kirimiri Forest

Percentage abundance of the macro-invertebrate families collected and the total number of individuals are shown below.

Abundance (%)

$$= \frac{Means\ of\ Individuals\ collected\ per\ family}{Total\ mean\ of\ \ all\ the\ families\ collected} x100$$

Data Analysis

The data on the Macro-invertebrate's abundance obtained were log transformed and analyzed using Scientific Analysis System (SAS) version 9.4 and the significance means were separated using Least Significance Difference (LSD).

IV. Results

1. Major Grouping of Macro Invertebrates in Kirimiri Forest

The forest recorded the highest mean number of functional groups having 7 decomposers, 5 herbivores, 6 omnivores and 5 predators. The Napier plantation had the least number of functional macro-invertebrates that is 1 decomposer, 2 herbivores, 3 omnivores and lastly 1 predator (Figure 2). The last habitat type was the tea plantation. It had 4 decomposers, 3 herbivores, 4 omnivores and 2 predators.

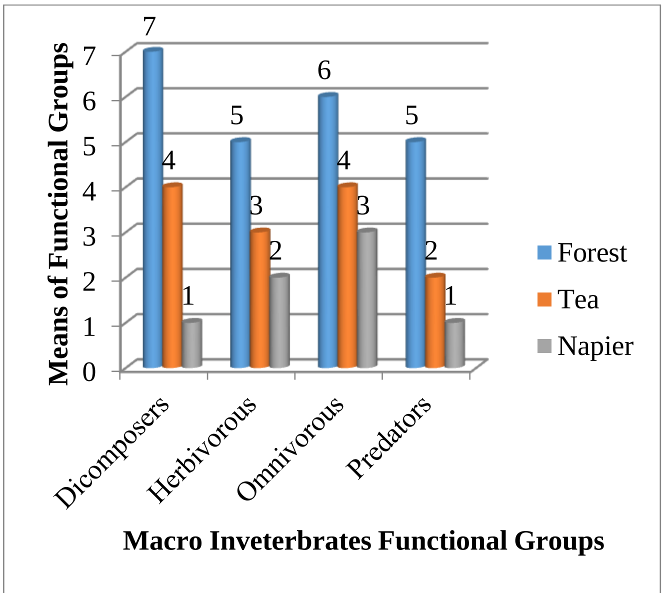

Figure 2: *Functional groups as per the three Habitats*

2. Macro-invertebrate Family Variation in Tea, Forest and Napier grass plantation

A total of 514 macro invertebrates were trapped in the study using pit fall traps. Intact forest had the highest number of 174 of invertebrates trapped with a mean of 6.91 followed by Napier plantation with 172 (Mean 5.49) and lastly tea plantation had 168 (Mean 4.32). Total means of macro invertebrates in the three vegetation types were different and significant (Figure 3).

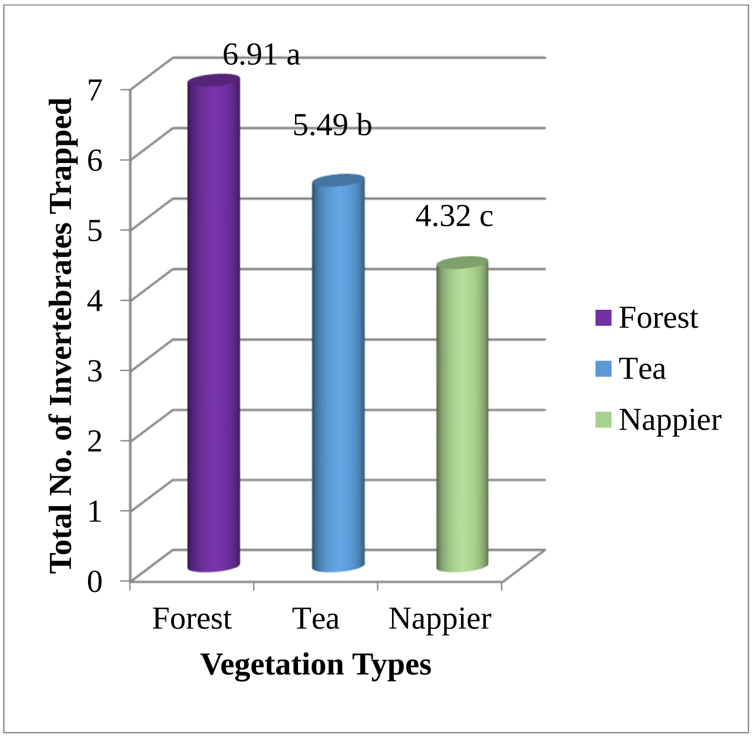

Figure 3: Graph showing means of Macro-invertebrates distribution across three different vegetation types

Vegetation type had statistical significant effect on distribution of macro-invertebrates **(**α=0.05). Mean of *Polydesmidae spp* were significantly different ($p<0.05$; Table 1) across the three vegetation types. *Polydesmidae spp* mean difference between the forest and tea vegetation types was 0.046 and was not statistically significant while difference between Forest/ Napier grass, Napier grass/ Tea were 0.589 and 0.733 and were statistically significant. The three vegetation types studied had no effect on the distribution of *Lulidae* significantly ($p>0.05$; Table 1). However, the difference between *Lullidae spp* means in Forest and Napier was 0.2796 and was significantly different. Vegetation type effected the distribution of *Polydesmidae* significantly ($p<0.05$; Table 1). The mean difference of *Polydesmidae spp* between Forest and Napier grass was 0.5575 and was significant. Nonetheless, *Polydesmidae spp* mean difference between the Napier/Tea and Forest/Tea vegetation types were not significant. The effect of vegetation type on the distribution of *Julidae spp* was statistically significant ($p<0.05$; Table 1). *Julidae spp* mean differences between the Napier/Tea and Forest/ Napier vegetation types were 0.348 and 0.458 and were significant. However, *Julidae spp* mean difference between Forest and tea was not significant. *Pyralidae spp* distribution was affected by the vegetation type significantly ($p<0.05$; Table 1). The mean difference of *Pyralidae spp* between the Napier/Tea and Forest/ Tea vegetation types were not significant. However, *Pyralidae spp* mean difference between Forest and Napier was 0.392 and was significant. Distribution of *Gnaphosidae spp* was affected by the vegetation type significantly ($p<0.05$; Table 1). The mean differences of *Gnaphosidae* were significant between the Napier/Tea (0.23), Napier/Forest (0.518) and Forest/ Tea (0.288) vegetation types. *Apiidae* spp distribution was affected by the vegetation type of the study area significantly ($p<0.05$; $F (7, 18)$. Mean difference of *Apiidae spp* trapped were significant between the Napier/Tea (0.478) and Napier/Forest (0.472). Nonetheless, means difference of *Apiidae spp* between vegetation types, tea/ forest/ (0.07) was not statistically significance (Table 1). The distribution of *Termitidae*, *Lymantriidae*, *Saturnidae*, *Formicidae*, *Ariolimacidae*, *Arionidae*, *Scarabaeidae* in the in the study area were not affected with the vegetation type significantly ($p>0.05$; Table 1). The mean difference of these macro-invertebrates between the Napier/Tea, Napier/Forest and forest/ tea vegetation types were not statistically significant. In Tea plantation, *Platydesmidae spp* (14.185) and *Jullidae spp* (10.95) were the most dominant macro-invertebrates. The least observed macro-invertebrates in Tea plantation were *Formicidae with a mean of* 2.994 as compared to Forest (4.973) and then Napier (4.323). In the forest, the dominant macro invertebrate was *Polydesmidae spp* with the mean of 18.833 as compared to Tea (9.554) and then Napier (5.217). The least observed macro-invertebrates in the forest were *Curculionidae spp* with a mean of 3.203 (Table 1). In the Napier grass with macro-invertebrate overall mean of 4.32, the dominant macro-invertebrate was *Arionidae spp* with a mean of (6.479) as compared to Forest (6.931) and then Tea (5.757). The second and third dominant species in the Napier plantation were *Termitidae spp* (6.122) as compared to Forest (6.679) and then Tea (8.1). *Apidae spp* was the least observed macro-invertebrate in the Napier plantation with the mean of 2.245 as compared to Forest (6.649) and then Tea (6.755). In the tea plantation with overall macro-invertebrate means of 5.49, macro invertebrates *Gryllidae* spp, *Termitidae spp*, *Jullidae spp*, *Lullidae spp*, *Polydesmidae spp*, their means above the overall mean (Table 1: Figure 2). Forest had overall mean of 6.91, macro invertebrates which include Jullidae *spp*, *Lullidae spp*, *Platydesmidae spp*, *Polydesmidae spp*, and *Gnaphosidae spp* had their means above the overall mean. (Table 1).

Table 1: Comparison of Selected Macro invertebrates Across Kirimiri Forest

Invertebrate Family	Tea	Forest	Nappier	Means	Lsd	PValue	CV
Gryllidae	3.432	7.042	3.851	4.059	2.704	0.681	55.217
Termitidae	8.0890	6.679	6.122	6.915	1.578	0.412	18.331
Julidae	10.95 ^{a}	12.994 ^{a}	4.530 ^{b}	8.056	1.995	0.017	25.248
Lulidae	10.611	9.196	5.574	8.163	1.820	0.086	22.133
Lymantriidae	7.31	7.974	3.689	5.991	2.312	0.130	36.371
Saturnidae	4.68	5.924	3.582	4.431	2.014	0.319	35.489
Platydesmidae	14.185 ^{b}	15.771 ^{a}	4.063 ^{a}	9.687	1.552	<.0001	15.017
Polydesmidae	9.554 ^{ab}	18.833 ^{a}	5.217 ^{b}	9.791	2.000	0.0069	23.620
Pyralidae	4.344 ^{ab}	6.90 ^{a}	2.798 ^{b}	4.377	1.799	0.0204	30.857
Ariolimacidae	4.647	5.886	4.647	4.802	2.254	0.6001	40.302
Formicidae	2.994	4.973	4.323	4.007	2.361	0.429	48.145
Arionidae	5.757	6.931	6.479	6.370	2.143	0.862	32.014
Scarabaeidae	4.701	5.532	5.258	5.152	2.518	0.923	43.808
Nitulidae	4.234	4.451	3.388	3.997	1.849	0.590	34.526
Curculionidae	4.472	3.203	3.464	3.675	1.722	0.395	32.517
Caribidae	5.335	5.895	3.464	3.444	2.118	0.289	37.307
Gnaphosidae	4.234 ^{b}	8.226 ^{a}	2.492 ^{b}	4.428	1.614	0.001	24.976
Tubificidae	4.579	6.008	4.740	5.071	2.805	0.818	49.338
Lycosidae	3.464	3.87	2.994	3.424	2.198	0.772	49.741
Ellobiidae	4.011	3.932	3.950	3.964	3.041	0.999	62.812
Apidae	6.755 ^{a}	6.649 ^{a}	2.245 ^{b}	3.833	1.766	0.002	28.699
TOTAL MEAN	5.49	6.91	4.42				

*Means followed by the same latter rows are not significantly different

*LSD= Least Significance Difference, MSE = Mean Square Errors, F= F-value

3. The Overall Variation of Macro-Invertebrates Species in Kirimiri Forest

The macro invertebrate spp abundance in Kirimiri forest varied from one family to the next. The most abundant macro-invertebrate family was *Gnaphosidae spp* with percent abundance of 7.45 % (Table 2), the second was *Platydesmidae spp* (5.83%) and third was *Polydesmidae spp* (5.82 %). The least abundance species was *Tubificidae spp* (2.09%), followed by *Nitulidae spp* (2.12).

Table 2: Overall Macro-invertebrate Percent Abundance Across Kirimiri Forest

Family	Mean	Percentage
Gnaphosidae	12.52	7.45
Platydesmidae	9.80	5.83
Polydesmidae	9.79	5.82
Julidae	8.85	5.26
Lulidae	7.76	4.62
Caribidae	7.22	4.29
Termitidae	6.92	4.11
Gryllidae	6.57	3.91
Lymantriidae	6.22	3.70
Ariolimacidae	5.76	3.43
Scarabaeidae	5.60	3.33
Ellobiidae	5.51	3.28
Cantharidae	5.48	3.26
Arionidae	5.20	3.10
Arthoracophoridae	5.11	3.04
Apidae	4.95	2.94
Hydrometridae	4.80	2.85
Arionidae	4.65	2.77
Curculionidae	4.54	2.70
Pyralidae	4.45	2.65
Limacidae	4.45	2.65

Hydrachnidae	4.40	2.62
Saturnidae	4.30	2.56
Lycosidae	4.26	2.53
Formicidae	4.13	2.46
Ammodesmidae	4.02	2.39
Gryllidae	3.78	2.25
Nitulidae	3.57	2.12
Tubificidae	3.52	2.09
Overall	168.10	100

V. Discussion

Forest had the highest abundance, followed by tea plantation and lastly the Napier grass plantation. The number of macro-invertebrates differed significantly within the three habitats. Our findings are similar to those reported by McBrayer *et al.*, [28] and supported by the report of Villalobos *et al.*, [29] that suggested that highest abundance in terms of communities occurs in the forest. As explained by Welemariam *et al*. [29], high moisture content in the forest as well as high soil organic carbon in closed up forested areas may support macro-invertebrate reproduction and growth. Forest fragmentation may cause 'edge effect', which in the long run may be imposed onto the existing flora and fauna [30]. Edge partitions physical adaphic and edaphic factors of the habitat [13] [32]. This argument may explain the variation and high number of invertebrates in the forest when compared to other habitats studied such as Tea and Napier plantation. Further, intact forest area experiences minimal anthropogenic activities such as grazing which may affect the microhabitat for macro-invertebrate's abundance [30]. Decomposers were the leading functional group in the forest, as compared to the Napier plantation and Tea farm. We did not find any similar study to compare these results. However, that can be explained by the various parameters at the boundary edges that determine the direction or magnitude with which an organism would move [33]. According to Doğramaci *et al*. [34], species that are not adapted to the high moisture, levels in the forest may prefer dryer parts. The high abundance of decomposers in the forest and tea plantation can be attributed to the difference in soil vegetation covers, which greatly influence temperature by creating a shady environment and provide the decomposers with the organic matter for decomposition purposes [34]. In addition, decomposer invertebrates differ in the three habitats due to variations in local climatic conditions [28]. According to Göltenboth and Widmann [35], decomposers may be present within the forest in high numbers as a result of higher decomposition rates on the forest floors. Higher decomposition rate is influenced by litter fall, higher degree of lignification, moisture, abundant decomposer community and conducive temperature [35]. This is different from the Napier and Tea plantation with single dorminant plantation. *Platydesmidae spp* was the most abundant family in the tea plantation. This result differs with the finding of Alexander and Otte [36] which reported that *Gryllidae* are the most abundant family in plantations. This may be associated with the fact that Gryllidae family including crickets feed on vegetation matter and sometimes voraciously prey on other insects present in the plantations which may have been limited by monoculture of Napier plantation. The abundance of *Platydesmidae* in the plantations is linked to the leaf litter and the soil quality [37]. *Formicidae* was the least abundant family in the tea plantation. Our results differ with the earlier studies by reported by Graham *et al.* [38] that observed *Formicidae* as the most abundant in the undisturbed and moderately disturbed areas of the forest. Parts of the tea plantations bordering the forest had high amount of macro-invertebrates trapped. Higher invertebrate numbers in these areas may be due to declined light intensity as well as other abiotic extremes [31] [10] that is conducive to certain organisms [39] (Thongphak, Iwai, & Chauasavathi, 2015). *Polydesmidae* recorded the highest abundance in the intact forest areas. These results differ from those of Gichana *et al*. [16]. The dominance of this macro-invertebrate in the forest may be as a result of less habitat disturbance and high moisture content in the forest [39] (Thongphak, Iwai, & Chauasavathi, 2015) [30]. The other reason for the difference may be due to difference in study sites having varied micro climate parameters [35]. Molluscs were abundant in the forest. The finding corroborates with those of Oke and Chokor [41]. According to Göltenboth and Widmann [35], Molluscs such as snails are sensitive to habitat change and therefore dominates intact forest having conducive environment for development. Thus, lower number of molluscs observed in the Tea and Napier plantation was due to monoculture and therefore signifying disturbance [41]. The finding on *Polydesmidae* as the most abundant macro-invertebrate in the forest differs to those of Bouchard *et al.* [42]. Certain macro-invertebrates including *Termitidae, Cantharidae, Saturnidae, Ellobiidae* and *Lycosidae* were captured across all habitats in almost equal frequency in our study indicating that they were habitat non-specific. Thus, these habitat nonspecific macro invertebrates could cross and inhabit intact forest, Tea plantation as well as Napier plantation. Physiologically, such organisms are able to survive since they regulate or tolerate harsh non-conducive habitat changes such as reduced food source, water loss and niche heterogeneity [43] [44]. Abundance of *Termitidae* family in Tea plantation may be due to the vegetation cover, which they decompose. *Termitidae* also lives in colonies by forming nests over the ground where they are considered as the main decomposer of plant litter [44] [45]. In Napier plantation, the most observed macro-invertebrate were *Arionidae spp* followed by *Termitidae spp*. We did not find any related study. The higher number of the *Termitidae spp* in the plantations may be associated to leaf litter and the soil type. The lowest observed macro-invertebrate mean was *Apidae* and *Gnaphosidae*. These results differ to those of Sekiranda *et al.*, [17]. The lower abundance of *Apidae* can be attributed to the monoculture nature of Napier farm since *Apidae* family is reported to do well in a polyculture plantation [46]. *Thiaridae* had the highest abundance across the three habitats followed by *Polydesmidae* and *Platydesmidae* respectively. These findings are different from those of Stuhl [47] and Ukam *et al.* [48]. This can be explained by the fact that *Platydesmidae* occupies specific localities. *Curculionidae* was the least abundant macro-invertebrate across the three habitats followed by *Lycosidae* and then finally *Nitulidae*. These results are different from Stuhl [47] which reported that *Nitulidae* were the most abundant family in a study. This can be explained by the dry nature in some parts of the habitats sampled.

VI. Conclusion and Recommendation

Disparities in ground dwelling macro invertebrate's distribution in the three different habitats points to the negative effects caused by human activities onto the soil. Continued practice of these activities may end up having a negative effect on the environment hence causing ecological imbalance and reduced functions of macro invertebrates onto the soil such as aeration. We recommend further research on the effect of farming practices such as fertilizer application on ground dwelling macro invertebrate's abundance and distribution.

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