Research Article

Impact of Different Land-Use Systems on Soil Physicochemical Properties and Macrofauna Abundance in the Humid Tropics of Cameroon

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The impact of different land-use systems on some soil physicochemical properties and macrofauna abundance in the humid tropics of Cameroon was studied. The land-use types included secondary forest (SF), oil palm plantation (PP), banana plantation (BP), sugarcane plantation (SP), and rubber plantation (RP). Soil particle size distribution, bulk density (BD), pH, organic matter (OM), and number of macrofauna were evaluated. The results showed that OM and number of macrofauna were higher in the SF than in the other land-use types. Pearson's correlation analysis carried out to determine the relationship between OM and BD showed that OM and BD was strongly negatively related with correlation coefficient of -0.9653 . It also showed a strong significant negative correlation between BD and ants population ($r = -0.8828$) and between soil pH and number of earthworms ($r = -0.9072$). Based on the results, the SF produced more organic matter and higher number of macrofauna. However, the OM of the other land uses was not low; hence, it could be beneficial to return plant residues to the field for maintaining soil quality.

1. Introduction

Environmental degradation caused by inappropriate land use is a worldwide problem that has attracted attention in sustainable agricultural production systems [1]. The productivity and sustainability of soil depends on dynamic equilibrium among its physical, chemical, and biological properties [2]. These properties are continuously influenced by land uses. According to Di et al. [3], agricultural management practices can largely influence the quality of the soil

which in turn is intrinsically linked to the sustainability of agroecosystem functions and productivity. Therefore, successful agriculture requires the sustainable use of soil resources as soil could easily lose its quality and quantity within a short period of time [4]. Soil health maintenance is essential for sustained food productivity, the decomposition of wastes, storage of heat, sequestration of carbon, and the exchange of gases. Since 1945, it is estimated that 38% of the cultivated areas in the world have been degraded. Annually, approximately 24 billion tons of topsoil is lost. This is

equivalent to about 9.6 million hectares of land. Therefore, soil degradation and/or changes in soil quality that result from wind and water erosion, salinization, losses of organic matter and nutrients, or soil compaction are of great concern in every agricultural region in the world [5]. In an attempt to reverse the trend of declining soil quality, recent studies have focused on identifying suitable soil management practices. However, soil quality cannot be directly measured, and soil quality information is usually deduced from observed or modelled soil physical, chemical, or biological attributes [6, 7]. Within the context of agricultural production, Karlen et al. [8] attributed high soil quality to be equivalent to long-term high productivity and the system resiliency without significant soil or environmental degradation [3]. Larson and Pierce [9] outlined five soil functions that may be used as criteria for judging the soil quality: to hold and release water to plants, streams, and subsoil; to hold and release nutrients and other chemicals; to promote and sustain root growth; to respond to management and resist degradation; and to maintain suitable soil biotic habitats.

Macrofauna found in soil and surface litter are known to play a central role in soil processes such as nutrient cycling, organic matter decomposition, and improvement of physical attributes such as aggregation, porosity, and water infiltration [10, 11]. These small organisms, such as insects and other invertebrates, play a vital role in the production and maintenance of healthy soils, and therefore are key elements in the development of sustainable agriculture and forestry [12].

Human activities frequently cause the degradation of soil environment which leads to reduction in the number of animal and plant communities, where species able to bear stress predominate and rare taxa decrease in abundance or disappear [13]. With continuous cultivation, physical properties and productivity of many soils commonly decline due to decrease in organic matter content and soil pH [14]. Changes in soil properties caused by cultivation and management and their consequences to soil productivity have generated significant research concern for many years [15]. Information on the effects of land management on soil physicochemical properties and upon soil invertebrate communities under different land-use systems in the humid tropics of Cameroon is scanty and thus makes it difficult to recommend or adopt appropriate soil conservation and management practices. The objective of this study was therefore to evaluate the land-use effects on selected soil physicochemical properties and macrofauna abundance.

2. Materials and Methods

2.1. Study Site and Soil. For the purpose of this study, five different land-use systems were selected in Fako Division in the Southwest region of Cameroon known for intensive agricultural production. This area is characterized by two main seasons: the rainy season from mid-March to mid-November and the dry season from mid-November to mid-March [16]. It has a temperature ranging between 20°C and 28°C and annual rainfall of about 3000–5000 mm. The area is composed of undulating high and low lands with many

rocks and gravels due to volcanic eruptions. The land-use types include secondary forest (SF), banana plantation (BP), oil palm plantation (PP), and sugarcane plantation (SP), all located in Buea subdivision and rubber plantation (RP) in Muyuka subdivision. The exact locations of the fields and soil types are presented in Table 1. The soils in BP, PP, SP, and SF belong to the Mussaka series and RP to the Ekona series. Soils in these areas are formed on older mudflows and have a well-developed argillic horizon. They belong to one and the same continuum, with properties which are changing gradually [17].

2.2. Description of Land Use. The secondary forest was surrounded by oil palm plantation, cocoa farm, and other mixed cropping farms consisting of plantains, cassava, and cocoyams. The banana plantation is owned by the Cameroon Development Corporation (CDC) and was established from 2004 to 2007. Several agronomic/agricultural practices are employed, and these include periodic application of agrochemicals (insecticides, nematicides, fungicides, herbicides, molluscicides, and different kinds of fertilizers and lime), leaf and sucker pruning as well as the use of understorey irrigation system. Field residues (pseudostems, premature fruits, and leaves) and postharvest residue (penducles) are left to rot in the field. The oil palm plantation is also owned by CDC with oil palms that were planted since the year 1985. Field residues (harvested fronds and male inflorescence) are left to rot in the farm. Unlike the banana plantation, the farm was under fallow for 6 months. The sugarcane plantation belongs to a smallholder farmer and was established in 1986. Agrochemicals were never used, and pruned leaves were the only field residues found in the farm. The rubber plantation is cultivated by the CDC, and the farm was established in 1984. The only farm residues were litter falls.

2.3. Soil Sampling, Processing, and Physicochemical Analysis. In all the sites selected, for soil sampling, the aforementioned crops were grown as the sole crops in the different land-use systems. The factors considered before choosing the sites were all the land-use systems were of the same soil type (volcanic soil), have similar climatic conditions, and operate within the same soil-forming factors.

2.3.1. Physicochemical Properties. In October 2016, undisturbed soil samples were collected in triplicate from each land use, per field per depth at 0–5 cm, 5–10 cm, 10–15 cm, and 15–20 cm with a 100 cm³ cylinder for bulk density studies. A soil auger was used to collect composite soil samples for the study of pH, particle size distribution, and organic matter contents. Bulk density was determined according to Blake and Hartge [18]. The values for the 0–20 cm soil layer were obtained from the mean of 0–5 cm, 5–10 cm, 10–15 cm, and 15–20 cm. The organic matter contents were determined by the loss on the ignition method and the soil particle size distribution for each sample by the pipette method according to Gee and Bauder [19], from

TABLE 1: Description of sampling sites used for the study.

No.	Land-use type	Location	Longitude	Latitude	Elevation (m)	Soil type
1	RP	Mile 29	04° 14.787'	009° 21.876'	195	Volcanic soil
2	PP	Bowanda	04° 10.671'	009° 19.900'	365	Volcanic soil
3	SP	Moli	04° 11.640'	009° 18.681'	516	Volcanic soil
4	SF	Mussaka	04° 10.371'	009° 19.623'	371	Volcanic soil
5	BP	Mussaka	04° 11.429'	009° 19.281'	487	Volcanic soil

RP, rubber plantation; PP, oil palm plantation; SP, sugarcane plantation; SF, secondary forest; BP, banana plantation (all the plantations are monocultures).

which the soil textural classes were obtained. Soil pH (1 : 2.5 w/v soil/water ratio) was determined using a pH meter.

2.4. Macrofauna Sampling and Data Collection. The humid forest zone has a large and diverse soil-associated fauna that strongly influence soil properties and development. Data on the invertebrate fauna composition on the different land-use systems were collected above ground and within soil/litter.

2.4.1. Above-Ground Data Collection. Ten different positions were selected randomly on the different sites, and a sweeping net was used to collect the organisms [20] found on the low vegetation (about 0.5 m above soil) found under the main vegetation. The sweep net was swept on the low vegetation, and the organisms captured inside the net were prevented from escaping by folding the opening of the sweep net immediately after sweeping. The different species of organisms captured were counted in situ according to the different species and recorded in a field hand book. This process was replicated three times on each selected position.

2.4.2. Litter/Below-Ground Sampling and Data Collection. This was done by random selection of different positions on the different land-use systems. A machete was used to till the upper surface of the soil at an area of 30 cm × 30 cm and a depth of 2 cm. The bulk of the tilled soil (together with the litters) was collected with hand covered by hand gloves and then placed inside labelled plastic bags. The openings of the plastic bags were sealed by tying it with a cord to prevent the soil organisms from escaping. This process was replicated ten times. The plastic bags containing the soil were transported to the laboratory of the Entomology/Nematology unit of the Institute of Agricultural Research for Development (IRAD) for counting and classification of the captured organisms. Samples for the macrofauna were taken from the same place where sampling for soil physicochemical analysis took place.

2.4.3. Counting of the Below-Ground Organisms. Each replicate of soil/litter samples carried to the laboratory was laid out separately on a plastic tray. Using an iron rod and a touch light, the soil samples were spread on a plastic tray and the organisms found within were placed on labelled small vials containing 70% alcohol. Each group of organisms was counted and then classified to at least the level of phylum, class, and order, although some were classified up to family or species level.

2.5. Statistical Analysis. One-way analysis of variance (ANOVA) was used to compare the effects of different land-use systems on soil physicochemical properties. Separation of the means of the soil properties was performed using the Tukey HSD test ($p < 0.05$). Correlations between macrofauna abundance and some selected soil physicochemical properties were determined by Pearson's correlation coefficient. For all the statistical analyses, JMP 5 statistical software was used.

3. Results and Discussion

3.1. Physicochemical Properties in the Different Land-Use Systems

3.1.1. Particle Size Distribution. The sand content recorded in sugarcane plantation was highest in the 0–20 cm layer followed by that of oil palm plantation, banana plantation, rubber plantation, and secondary forest whereas the silt content was found highest in the secondary forest followed by sugarcane plantation, rubber plantation, banana plantation, and then palm plantation. Generally, there were significant differences in the soil particle size distributions in the different land-use systems with the soil texture for oil palm plantation classified as clay soil, while banana plantation and rubber plantation ranged from clay to silty clay soils and sugarcane plantation and secondary forest ranged from silt loam to silty clay loam soils (Table 2).

3.1.2. Soil pH. The soil pH varied from 4.90–5.68 in the different land-use systems (Table 2) with banana plantation having the highest soil pH and oil palm the lowest. This high pH of banana plantation might be attributed to the periodic application of lime (dolomite) in the field. With the exception of oil palm plantation, no significant difference was observed among the land-use systems. However, oil palms grow well in the pH range of 4.3–6.5. It was also reported that the most suitable soil texture for oil palm plantation is sandy clay and silty clay [21]. The soil pHs could be categorized as very strongly acidic for soils in oil palm plantation, strongly acidic for sugarcane plantation and secondary forest, and moderately acidic for rubber and banana plantations [22]. The majority of tropical soils are acidic. Acidic soils ($\text{pH} < 5.5$) are widespread, especially in humid regions; they cover 30% of the world's total land area and 60% of the total area in the tropics [23]. The agricultural solution to acidic soils is therefore the application of lime to achieve pH favourable for most plants (5.5–7.5).

TABLE 2: pH, sand, silt, and clay properties in different land-use systems.

Land use	pH	Sand (%)	Silt (%)	Clay (%)	Textural class range
RP	5.66 (0.18)a	3.51 (1.21)bc	39.14 (3.35)b	57.34 (2.70)b	Clay-silty clay
PP	4.90 (0.04)b	8.44 (0.10)ab	18.76 (0.65)c	72.80 (0.74)a	Clay
SP	5.33 (0.02)a	10.35 (0.37)a	63.25 (2.39)a	26.74 9 (1.98)c	Silt loam-silty clay loam
SF	5.32 (0.01)a	3.12 (1.02)c	72.00 (1.95)a	25.24 (2.74)c	Silt loam-silty clay loam
BP	5.68 (0.07)a	5.68 (1.80)abc	33.77 (4.82)b	60.35 (5.97)ab	Clay-silty clay

Mean values with standard errors within the parenthesis. Column entries followed by the same letters are not significantly different at $p \leq 0.05$. RP, rubber plantation; PP, oil palm plantation; SP, sugarcane plantation; SF, secondary forest; BP, banana plantation (all the plantations are monocultures).

3.1.3. Soil Bulk Density (BD). The bulk density at 0–20 cm in all land uses varied from 0.91–1.21 g/cm³ with the trend of secondary forest < oil palm plantation < banana plantation < rubber plantation < sugarcane plantation with the mean values of 0.91, 1.06, 1.13, 1.16, and 1.21 g/cm³, respectively. The results showed that bulk density varied significantly ($P \leq 0.05$) among the land-use systems (Figure 1) except between sugarcane plantation and rubber plantation and between banana plantation and oil palm plantation. The highest bulk density was found in the soil under the sugarcane plantation followed by rubber and banana plantations. In contrast, the lowest bulk density was observed in the secondary forest followed by the palm plantation. The high bulk density of the croplands compared to the secondary forest might be as a result of intensive agricultural practices for croplands [24]. This is also consistent with the result of Oguike and Mbagwu [14]. Increase in bulk density as a result of conversion of forest to cultivated land is a reflection of the extent of soil degradation and has been demonstrated by many researchers [25]. High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth and poor movement of air and water through the soil [26].

3.1.4. Soil Organic Matter (OM). Soil organic matter for all land-use types from 0–20 cm depth ranges from a minimum in rubber plantation (14.32%) followed by sugarcane plantation (15.18%), banana plantation (17.45%), and oil palm plantation (18.10%) to a maximum in secondary forest (20.37%). The high OM in the forestland might be as a result of tree leaves, stems, barks, flowers, logs, and fruits. In addition, microorganisms, animals, and roots contribute to the increase of OM [27]. There were significant differences ($P \leq 0.05$) among the OM content of the land-use types except between oil palm and banana plantations and between sugarcane and rubber plantations (Figure 2). The high OM content also recorded in PP and BP might be as a result of plant residues that are abundantly available and which are returned to the soil in these environments. Salehi et al. [28] reported that the effects of trees on soil properties occur mostly due to the increase of organic matter and the release of nutrients from it. Although the OM contents of soils under RP and SP were lower than those of SF, PP, and BP, the values were also high because the leaf litters of these plants are left to rot in the fields.

3.2. Classification of Organisms Collected. Of the total of 1579 individual organisms collected from both the sweep netting (810 individuals) and soil/litter extraction (769 individuals)

FIGURE 1: Effect of land-use change on soil bulk density (BD).

FIGURE 2: Effect of land use on soil organic matter.

(Figure 3), twenty-one (21) species were identified/classified up to class or order level while three (03) were unidentified (Table 3). The total numbers of individual organisms were highest in the forest and in the oil palm plantation and lowest in the sugarcane plantation. With respect to the different collection methods, highest number of individual organisms was recorded from soil-litter extracts in the forest. From sweep netting, the highest number of individual organisms captured was from the palm plantation (PP) (Figure 3). This may be due to the abundance and diversity of floral resources in the fallow oil palm plantation.

FIGURE 3: Total number of individual organisms collected from sweep nets and soil litter from different land-use systems.

TABLE 3: Phylum, class, and potential role of species recorded from sweep nets and soil litter from different land-use systems in Fako Division, SW region, Cameroon.

Species/organisms	Presence/absence		Phylum	Class (order) (family)	Potential ecological role
	Sweep net	Soil litter			
Ants	Present	Present	Arthropoda	Insecta (Hymenoptera) (Formicidae)	Predation, soil fertility
True flies	Present	Absent	Arthropoda	Insecta (Diptera) (Muscidae)	Pollination, decomposer, soil fertility
Spider	Present	Present	Arthropoda	Arachnida (Araneae)	Predation
Fruit flies	Present	Absent	Arthropoda	Insecta (Diptera) (Tephritidae)	Pest
Beetle/weevils	Present	Absent	Arthropoda	Insecta (Coleoptera)	Pest, soil fertility
Cricket	Present	Present	Arthropoda	Insecta (Orthoptera)	Pest
Wasp	Present	Absent	Arthropoda	Insecta (Hymenoptera)	Predation, parasitoidism, pollination
Grasshoppers	Present	Present	Arthropoda	Insecta (Orthoptera)	Pest
Termites	Present	Present	Arthropoda	Insecta (Isoptera)	Pest, soil fertility
Cicada	Present	Absent	Arthropoda	Insecta (Hemiptera)	Pest
Bugs	Present	Absent	Arthropoda	Insecta (Homoptera)	Pest
Mosquito	Present	Absent	Arthropoda	Insecta (Diptera) (Culicidae)	Pest
Caterpillar	Present	Absent	Arthropoda	Insecta (Lepidoptera)	Pest
Millipede	Present	Present	Arthropoda	Diplopoda	Soil fertility
Snail	Present	Present	Mollusca	Gastropoda (Achatinidae) (mainly <i>Limicolaria</i> spp)	Pest
Centipede	Absent	Present	Arthropoda	(Chilopoda)	Predation
Cockroach	Present	Absent	Arthropoda	Insecta (Blattodea)	Pest
Moth	Present	Absent	Arthropoda	Insecta (Lepidoptera)	Pollinator
Earthworm	Absent	Present	Annelida	Oligochaeta	Soil fertility
Unidentified unknown insect larva	Absent	Present	Arthropoda	Insecta	Not known
Earwigs	Absent	Present	Arthropoda	Insecta (Dermaptera)	Predation
Slugs	Absent	Present	Mollusca	Gastropoda	Pest
Unidentified insect	Absent	Present	Arthropoda	Insecta	Not known
Unidentified arachnid	Absent	Present	Arthropoda	Arachnida	Predator

The total number of species recorded from the different land-use systems varied based on the collection methods used (Figure 4). From sweep netting, the highest number of species captured was from the sugarcane plantation (SP) and lowest from the forest (SF), while from the soil-litter extraction, the highest number of species was from forest and lowest from sugarcane plantation. Rossi and Blanchart [11] mentioned that tropical forests have higher densities of soil macrofauna compared to cultivated lands. This high number of soil macrofauna for the forestland might be as a result of its high organic matter content. This argument was strengthened by the fact that forestlands have a greater diversity and availability of food substrate for the soil fauna, fueled by high cycling of leaves and twigs in the forest litter [29]. According to Neeher [30], plant directly affects soil biota by generating inputs of organic matter above- and below-ground and indirectly by the physical effects of shading, soil protection, and uptake of water and nutrients by roots. In the forest, there is usually intense cycling of fine roots in the surface layer, which contribute as a nutrient substrate for soil fauna, thus favoring their multiplication. Rossi and Blanchart [11] also showed that macroinvertebrate communities also respond to environmental disturbance induced by land-use management.

3.2.1. Proportion of the Organisms Collected. First, the 24 species recorded were from three animal phyla: arthropoda, annelida, and mollusca. Majority of these species were arthropods (88%) and then mollusks and annelids (8% and 4%, respectively). Of this arthropod, the majority (81%) were from the class Insecta, 9% for Arachnida, and 5% each for Chilopoda and Diplopoda. The identified insects were from 10 orders, with most from the class Insecta (Table 3). Menezes and Cabrera-Davila [31] found out that of the over 7000 epigeous organisms collected from two different land-use systems, the predominant species were mainly insects particularly coleopterans and hymenopterans. All these show the importance of arthropods and most especially insects as biotic components in terrestrial ecosystems such as the ones in this research. Several reports have also shown the leading abundance of insects in natural and agroecosystems as well as their ecological role [11, 31–33].

3.2.2. Potential Ecological Role of the Organisms Collected. Generally, all organisms found in an ecosystem have ecological niches which include what they do in such a system. In this research, organisms recorded were also linked to certain ecological role in the land-use systems as a result of interactions within themselves or with other biotic and abiotic factors in the ecosystems. For the organisms in Table 3, the potential positive ecological role included predation, parasitoidism, improvement/maintenance of soil fertility, and pollination while the negative role is that some are pests. The proportion of these roles is shown in Figure 5, with pest having the highest (41%), followed by predation and soil fertility improvement/maintenance (both 21%

FIGURE 4: Total number of species captured from sweep nets and soil-litter extractions in the different land-use systems.

each), pollination and unidentified roles (each 7%), and parasitoidism (3%). Ponde et al. [33] showed that most animal and microbial groups are negatively affected by agricultural intensification.

3.3. Relative Abundance of Key Species. The key species were selected based on their potential role as environmental bioindicators and as pests, and these include earthworms, ants, beetles/weevils, snails, and spiders. For species captured in the soil litter, with the exception of relative abundance of snails (mainly *Limicolaria* species) and earthworms that were highest in the banana and palm plantations, respectively, the highest numbers of ants were from the forest (Table 4). Contrary to the case of snails, the total numbers of the other organisms were lowest in the banana plantations. This might be due to many different pesticides (including WHO class 1a pesticides such as terbufos and oxamyl) that have been or are being applied frequently in the banana plantations in the country [34]. Mongyeh et al. [35] and Okolle et al. [36] have reported the high impact of terbufos on mortality of banana borer weevils, ants, and earthworms. These chemicals therefore create an unfavourable environment, repelling and killing or affecting the reproductive capacity of especially the soil-dwelling organisms. Of recent, snails (*Limicolaria spp*) have become serious problem on banana fruits in the plantations of Cameroon especially during the rainy season. Unlike the distribution cases of soil-litter organisms, the abundance of these organisms captured from sweep nets varied with respect to the different land-use systems (Table 4). Earthworms were not caught while the number of snails collected was few. Highest numbers of beetles and spiders were caught in the rubber plantation. Ants were highest in the SF and lowest

FIGURE 5: Proportion of potential ecological role of the organisms recorded.

TABLE 4: Relative abundance (%) of key species collected from sweep net and soil litter on different land-use systems.

Land use	Earthworms		Ants		Beetles/weevils		Spiders		Snails		Fruit flies		Mosquitoes	
	Sweep	Litter	Sweep	Litter	Sweep	Litter	Sweep	Litter	Sweep	Litter	Sweep	Litter	Sweep	Litter
SF	0	11.6	53.5	62.2	5.1	3.1	10.1	13.6	0	1.7	1.0	0	2.0	0
PP	0	31.9	49.4	25.4	0.4	2.2	16.5	7.2	0	3.6	0	0	0	0
BP	0	4.6	16.8	3.1	0.5	0	0.5	10	0	76.2	38.9	0	6.3	0
RP	0	23.3	42.9	12.2	11.0	2.2	32.2	12.2	0	13.3	2.5	0	6.1	0
SP	0	21.4	12.6	53.0	10.7	1.7	10.7	2.6	0	7.7	1.0	0	4.9	0

TABLE 5: Pearson's correlation matrix of some selected soil physicochemical properties and macrofauna abundance.

	pH	OM	BD	Earthworm	Ant	Beetle/weevil	Spider	Snail	Fruit fly	Mosquito
pH	1									
OM	-0.3163	1								
BD	0.325	-0.9653**	1							
Earthworm	-0.9072*	0.3603	-0.4623	1						
Ant	-0.5932	0.7643	-0.8828*	0.7838	1					
Beetle/weevil	0.2904	-0.132	-0.097	0.128	0.2714	1				
Spider	-0.5396	0.5922	-0.6895	0.7843	0.8187	0.4089	1			
Snail	0.5794	0.0254	0.1892	-0.822	-0.6187	-0.5745	-0.6229	1		
Fruit fly	0.5658	0.0639	0.1519	-0.8061	-0.5884	-0.5786	-0.5977	0.9993**	1	
Mosquito	0.9346*	-0.4438	0.5246	-0.9552*	-0.8085	0.0471	-0.6438	0.727	0.7087	1

**Correlation coefficient is significant at the 0.01 level. *Correlation coefficient is significant at the 0.05 level.

in the SP while spiders were highest in the RP but lowest in the BP. As for beetles/weevils, they were highest in the RP and lowest in the BP while fruit flies were highest in the BP. An interesting result was that mosquitoes (especially the tiger mosquitoes) were really high in the banana and rubber plantations. Irrigation water that usually settles on the banana stumps might be encouraging oviposition of these tiger mosquitoes.

3.4. Correlation between Soil Properties and Macrofauna Abundance. Correlation matrix of 10 variables representing various soil physicochemical properties and macrofauna number under different land-use systems revealed significant correlation in 6 variable pairs out of fifty-five pairs

(Table 5). This result confirmed the strong significant negative correlation between OM and BD ($r = -0.9653$). The decrease of soil organic matter (OM) by the conversion of the forestland into cultivated fields probably caused the higher bulk density in the cultivated soils [37]. Hajabbasi et al. [38] reported that deforestation and subsequent tillage practices resulted in nearly 20% increase in bulk density and 50% decrease in soil organic matter for a soil depth of 0–30 cm over 20 years in central Zagros. There was also a strong significant negative correlation between bulk density and ants population ($r = -0.8828$). Cerdà and Jurgensen [39] in their work on the influence of ants on soil and water losses from an orange orchard in eastern Spain found that in ant-affected soil, there was a reduction of soil bulk density, an increase in soil organic matter, and an increase in macropore

flow as compared to soil without ant activity. Soil pH was negatively correlated with earthworms abundance ($r = -0.9072$), indicating that at higher pH, there is a decrease in earthworm number. Similar negative correlation was obtained by Karmegam and Daniel [40].

4. Conclusion

This study evaluated some selected physicochemical properties of soils and macrofauna abundance under different land-use systems (i.e., secondary forest and oil palm, banana, rubber, and sugarcane plantations) operating within the same soil forming factors and climatic conditions. Several soil physicochemical properties varied significantly among land uses. The results revealed that organic matter content might be as a result of quantity and type of plant residues that are returned to the soil in these environments. The number and diversity of soil/litter fauna were influenced by the type of soil management practiced in the different land-use systems. Negative significant correlations were observed between pH and number of earthworms and between ants and bulk density. Like the case of the banana plantation, excessive use of pesticides such as organophosphates has detrimental effects on ground dwelling organisms such as coleopterans, ants, and earthworms. Therefore, encouraging farmers to return agricultural residues (farm or processed residues) to rot in their fields could replenish degraded soil quality parameters for sustainable agricultural production and productivity in the study area.

Data Availability

The data used to support the findings of this study are included within the article. However, the corresponding author can be contacted for further information if needed.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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