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Original Article

Impact of land use on the seasonal diversity of soil mesofauna in the Okomu Forest Reserve, Nigeria

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ABSTRACT

This study was carried out to examine the effect of land use systems on the seasonal diversity and abundance (A) of soil mesofauna in the Okomu Forest Reserve (OFR), Edo State, Nigeria. Three land use systems were considered for the study: Okomu National Park (ONP), the Okomu Rubber Plantation (ORP), and the Okomu Oil Palm Plantation (OOP). Two transect lines were laid with eight plots measuring 25 m × 25 m in size in each land use system. The data were collected during the dry and rainy seasons of the year using a systematic sampling method. Soil samples were collected at soil depths of 0–15 cm and 15–30 cm. Data were subjected to Shannon-Wiener Diversity Index (Hi) and analysis of variance. Soil mesofaunal diversity and abundance were greater during the rainy season (Hi = 19.91 and A = 8331). The ORP had the highest (Hi = 3.34 and A = 1548), followed by OOP (Hi = 3.32 and A = 1548) and ONP (Hi = 3.32 and A = 1396). The land-use system significantly ($p < 0.00$) influenced the diversity and abundance of the soil mesofauna. However, season significantly affected the diversity of soil mesofauna but had no significant ($p > 0.51$) effect on the A. Additionally, soil depth had no significant ($p > 0.33$) effect on the diversity but significantly ($p < 0.00$) influenced A. The diversity and abundance of soil mesofauna in the study area are attributed to plant-based energy and an influx of food sources in the soil.

KEYWORDS: *Abundance and diversity, Land use systems, Mesofauna, Season, Soil depth*

INTRODUCTION

Nigeria is an African country that is characterized by abundant flora and faunal diversity, a haracteristic that is common to other African tropical countries. The tropics, which are home to approximately 70% of global biodiversity, are also a treasure trove of insect diversity and are estimated to parallel the extent of plant diversity in this region (Bradshaw *et al.*, 2009; Crespo-Pérezet *et al.*, 2020). Nigeria's tropical rainforest and savannah vegetation zones lie within the Guinea Forests of West African Biodiversity Hotspots (Myers *et al.*, 2000; Giam, 2017). Soil mesofauna consists of small invertebrates between 0.2 and 2 mm in body length that live in soil or litter. These invertebrates, mainly mites and collembolans, actively control nutrient cycling through frequent predation by nematodes, protozoa, and fungi.(Rousseau *et al.*, 2018). Most interactions between mesofauna and microorganisms are mutualistic since these invertebrates fragment and moisten the plant residue when it passes through the gastrointestinal tract, after

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which it is then excreted as a fecal pellet (Lavelle, 1997; Moreira *et al.,* 2008; Garg & Chandel, 2010). When in contact with soil, these pellets are colonized by chemo-organotrophic microorganisms, which release mineral nutrients into the soil, especially ammonium ions, which can be absorbed by plants (Hendrix, 2000). Soils under native vegetation are usually poor in mineral nutrients and present high acidity because fertilizers are not applied and the pH is not corrected (Javed *et al.,* 2022). However, these soils have varied and numerous niches and high microbial activity, which supports a greater diversity of soil fauna than agricultural sites (Rosa *et al.,* 2015). Additionally, collembolans prefer fresh organic matter as a food source (Lavelle, 1997; Hendrix, 2000; Balasubramanian, 2017) and are positively correlated with carbon C content. The different carbon sources deposited in the soil at various stages of decomposition can lead to the development of a richer and more diversified community of soil invertebrates than those maintained in agricultural systems (Moço *et al.*, 2005; Battirola *et al.,* 2007; Khatoon *et al.,* 2017). The soil covered by leaf litter in forest systems promotes higher soil moisture and lower temperatures than does soil in agricultural systems (Achat *et al.,* 2015). This explains the greater occurrence of collembolans in natural forests because these conditions favour collembolan reproduction and development (Choi *et al.*, 2006; Pollierer & Scheu, 2017).

In the present study, soil mesofauna were sampled from three evenly distributed habitats in the Okomu Forest Reserve. The objective was to determine whether Nigeria is an African tropical country endowed with rich flora and fauna biodiversity, which is typical of most tropical countries. The tropics, which are home to approximately 70% of global biodiversity, are also a treasure trove of insect diversity and are estimated to parallel the extent of plant diversity in this region (Dagallier *et al.,* 2020).

MATERIALS AND METHODS

Study Area

This study was carried out in the Okomu Forest Reserve, which comprises Okomu National Park, the Okomu Rubber Plantation and the Okomu Oil Palm Plantation. The Okomu Forest Reserve is located between 5^0 9’ 0" and 5^0 19’ 30" east longitude and 6^0 15’ 0" and 6^0 25’ 30" North latitude. The reserve is set within 1,082 km² in Udo, Ovia South–West Local Government Area, Edo State, Nigeria. The topography is gentle, ranging between 30 and 60 meters above sea level.

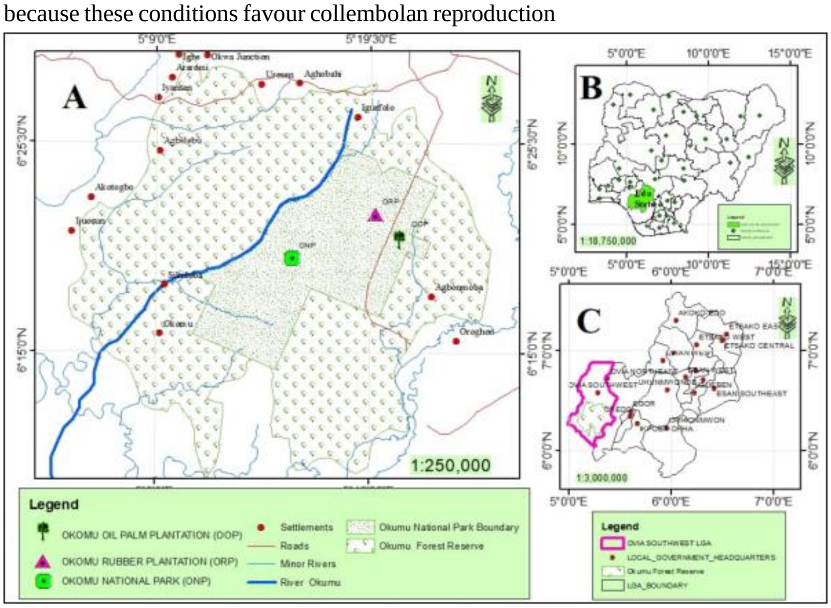

Figure 1: Map of the Okomu Forest Reserve

The mean annual rainfall is 2100 mm, and the mean monthly temperature is 27 °C. The mean monthly humidity is between 30.2% and 65% during the afternoon. Soils are acidic, with poor nutrients in sandy loam and a pH of 5.0 (Soladoye & Oni, 2000). The forest has a small fragment of rich forest that once covered the region but has continued to shrink owing to numerous encroachments. It is characterized by swamp forest, high forest, secondary forest, and open scrub. It serves as a habitat for many endangered species of flora and fauna, such as *Celtis zenkeri, Triplochiton scleroxylon, Antiaris toxicaria, Pycnanthus angolensis, Alstonia congensis,* and *Angolan pitta*; a grey parrot; a wrinkled hornbill; a fish eagle; hawks; and an African elephant (Okomu National Park, 2010). The Okomu Oil Palm Plantation and Rubber Plantation were established in 1976 as a Federal Government of Nigeria pilot project covering an area of 15,580 hectares, 12,500 of which could be planted with oil palm.

Data Collection

The study was conducted in two seasons: February 2020 (dry season) and September 2020 (rainy season). For instance, many insects and plants exhibit seasonal life cycles, which can lead to variations in biodiversity between dry and rainy seasons.

The study utilized a structured sampling design to assess biodiversity across different land use systems. Two 200-meter transects were established in three research locations, spaced 500 meters apart. Along each transect, four 25 m × 25 m plots were positioned at 20-meter intervals to mitigate edge effects. This setup allows for comprehensive sampling of species composition and abundance while reducing bias from habitat boundaries.

Soil samples were collected from eight plots in each of the three land use systems for the assessment of mesofauna diversity and abundance. Soil samples were collected at three points in each plot with the aid of a soil auger at soil depths of 0-15 cm and 15-30 cm. The experiment was conducted in a completely randomized design using the following experimental model:

$$Yij = N + Tj + Eij \qquad (1)$$

Y = individual observation, N =general mean, T=treatment effect, E =Experimental error

Mesofauna collection, isolation, and identification

The soil mesofauna were isolated in the laboratory using a flotation method. In the laboratory, the soil samples were subjected to ambient temperature and brought to a consistent moisture level to prevent disturbance to the mesofauna in the soil. The dried soil samples were sieved through a 2 mm pore-size mesh to remove larger debris and unwanted particles from the soil, leaving behind the mesofauna and smaller soil particles (Hendrix, 2000; Costa et al, 2018). After sieving, 100 grams of the isolated soil fraction containing mesofauna and smaller soil particles was placed in a Petri dish, and water was added. The soil–water mixture was gently agitated to create a soil suspension. This process was carried out to loosen the mesofauna and other fine particles from the soil matrix. The soil suspension was then left undisturbed for five minutes to allow the mesofauna and other particles to float on the surface of the water (Adeduntan, 2009). After the waiting period, a fine mesh sieve was used to skim the floating layer on the water surface to collect the isolated mesofauna. The collected material from the floating layer was placed on a petri dish for further examination under a microscope to identify and count the various species of soil microfauna in the samples.

Data Analyses

The data collected in the study were analyzed using Analysis of variance and LSD follow up test for significant mean. The soil mesofauna species encountered in each land use type were classified into families, and the order frequencies of occurrence were obtained for species abundance and evenness. The following biodiversity indices were used to compare biodiversity among the three land use systems:

Shannon–Wiener diversity index (H^I):

This was used to calculate the diversity index, which takes into account the evenness and abundance of each species in the different ecosystems (Kent & Coker, 1992). The following equation is used:

$$H^{I} = -\sum_{i=1}^{S} PiLn(Pi) \quad (2)$$

H^i = Shannon diversity index, S = the total number of species in the habitat,Pi = proportion S (species in the family) made up of the 1st species,Ln = Natural logarithm

Species Evenness (E)

Each ecosystem habitat was calculated by adopting Shannon's equitability index (H_E) of Kent and Coker (1992).

$$H_E = \frac{\sum_{i=1}^{S} PiLn(Pi)}{Ln(S)} \quad (3)$$

HE= Species evenness, S = the total number of species in the habitat, Pi = proportion S (species in the family) made up of the 1st species, Ln = natural logarithm

RESULTS

Table 1 shows the diversity, abundance, and evenness of soil mesofaunal species at different soil depths (0-15 cm and 15-30 cm) during the dry and rainy seasons in the study area. In total, 13,703 mesofaunal species were identified. Among these, 5,372 and 8,331 mesofaunal species were recorded during the dry and rainy seasons, respectively. During the rainy season, at a soil depth of 15-30 cm, both the Okomu Rubber Plantation and the Okomu Oil Palm Plantation exhibited the highest soil mesofaunal species abundance, with 1,548 individuals each, whereas the abundance in Okomu National Park was 1,396 individuals. Okomu Rubber Plantation, Okomu Oil Palm Plantation, and Okomu National Park recorded soil mesofaunal species abundances of 979, 934, and 928, respectively, at a 15-30 cm soil depth during the dry season. In the rainy season, the diversity index (H1) at a soil depth of 0-15 cm was highest in the Okomu Rubber Plantation (H1 = 3.34), followed by the Okomu Oil Palm Plantation (H1 = 3.32). The lowest diversity index during the rainy season was observed in Okomu National Park (H1 = 3.29) at a soil depth of 15-30 cm.

The species evenness of Okomu National Park, Okomu Rubber Plantation and Okomu Oil Palm Plantation was 0.99, 0.98 and 0.97, respectively, at a soil depth of 0-15 cm during the dry season. However, at 15-30 cm, the values for the Okomu National Park and Okomu Rubber Plantations were 0.98, while that for the Okomu Oil Palm Plantation was 0.97. During the rainy season, the value recorded for Okomu National Park and Okomu Rubber Plantation was 0.99, whereas the value recorded for Oil Palm Plantation was 0.98 at a soil depth of 0-15. The species evenness at 15-30 cm soil, Okomu Rubber Plantation and Oil Palm Plantation was recorded (0.99), and that at Okomu National Park was recorded (0.98).

Table 1: Diversity indices of soil mesofauna species in dry and rainy seasons in the study area

		Dry season			Rainy Season			
Land Use	**Soil Depth**	***H^I***	**E**	**Abundance**	***H^I***	**E**	**Abundance**	**Total**
ONP	0-15	3.09	0.99	818	3.32	0.99	1232	**2050**
	15-30	3.09	0.98	928	3.29	0.98	1396	**2324**
ORP	0-15	3.06	0.98	861	3.34	0.99	1265	**2126**
	15-30	3.07	0.98	979	3.32	0.99	1548	**2527**
OOP	0-15	3.04	0.97	852	3.32	0.98	1342	**2192**
	15-30	3.05	0.97	934	3.32	0.99	1548	**2482**
Total				**5372**			**8331**	**13703**

Hi : Shannon Weiner index; E: Evenness; ONP: Okomu National Park; ORP: Okomu Rubber Plantation; OOP: Okomu Oil Palm Plantation

Table 2 shows the abundance of soil mesofauna species in the three land-use systems during the rainy and dry season. During the rainy season, a total of 8,331 individual soil mesofauna species were recorded in all three land use systems. Among the identified species, *Hirschmanniella spp*. exhibited the highest abundance (360), followed by *Dorylus fimbriatus* (358), (343), and *Oniscus spp.* (343). The least abundant species were *Bdellozonium spp*., Tachina urcsine, and Chaetopeima spp., with abundances of 208, 195, and 194, respectively. The land use system with the greatest abundance of soil mesofauna species during the rainy season was the Okomu Oil Palm Plantation, with 1342 individuals. Okomu Rubber Plantation had 1265 individuals, while Okomu National Park had the least number of soil mesofauna (1232) at a soil depth of 0-15. However, at a soil depth of 15-30 cm, both the Okomu Rubber Plantation and the Okomu Oil Palm Plantation recorded 1548 individuals each, with the Okomu National Park containing 1396 soil mesofauna individuals. During the rainy season, the subsoil (15-30) exhibited a greater abundance of soil mesofaunal species than did the topsoil (0-15) in all the land use systems. During dry season,*Oniscus asellus* (343) was *Glomeris maginata* the most abundant species, followed by *Fulsomia candida* (328) and *Epidamaeus spp.* (326). In contrast, Chaetopeima spp., Dorylus fimbriatus, and Allolobophora trapezoides had the lowest abundances, at 117, 139 and 170, respectively. Okomu Rubber Plantation had the greatest abundance of soil mesofauna species at soil depths of 0-15 cm and 15-30 cm. Notably, the subsoil in all the land use systems exhibited the greatest abundance of soil mesofauna species during the dry season.

Table 3 shows the seasonal variation in the species composition of the soil mesofauna in the Okomu Forest Reserve. During the rainy season, the diversity of soil mesofaunal species across land use types was greater (28) than that in the dry season (22). The rainy season had 10) ten mesofauna soil species, namely, Eudrilus eugeniae, Glomeris maginata, Colpoda steinii, Dorylus fimbriatus, Myrmicaris striata, Pocellio scober, Acrobeloidea spp., Acanthamoeba pilyphages, Tullbagia granilata, and Epidamae, which were absent in the dry season. Conversely, four soil mesofaunal species, including pods, were present during the dry season but absent during the rainy season. Across all three land use systems, a total of 18 soil mesofaunal species were present during both the dry and rainy seasons.

Table 4 shows the effects of the land use systems, seasons and depths on the diversity and abundance of soil mesofauna in the study areas. The diversity indices of the soil mesofauna did not significantly differ among the three land use systems. The abundance of soil mesofauna did not significantly differ between the ORP and OOP treatments but was significantly greater than the abundance observed in the ONP treatment. The diversity and abundance of mesofauna were significantly (p 0.05) greater during the rainy season than during the dry season. The soil mesofauna diversity in the topsoil and subsoils was not significantly different, but the abundance of the soil mesofaunal community was significantly (p 0.05) greater in the subsoil than in the topsoil.

DISCUSSION

Influence of Land Use Systems on Soil Mesofauna Diversity and Abundance

The results of this study showed that the Okomu Rubber Plantation exhibited the highest diversity and abundance of soil mesofauna. In contrast, Okomu National Park had the lowest diversity and abundance of soil mesofaunal species. These findings indicate that the conversion of rainforest ecosystems to rubber plantations has led to an increase in the diversity and abundance of soil mesofauna, possibly due to the specific composition of litterfall and root exudates in the soil environment of rubber trees. This observation aligns with the work of Dijkstra *et al.* (2013), who reported that root turnover and root exudate influx are the primary sources of readily available or labile carbon, which drives soil microbial activities. Moreover, the expansion of plant-based energy channels in the soil food of oil palm plantations, as indicated by Winda *et al.* (2019), could also contribute to the high diversity and abundance of soil mesofaunal species.

Table 2: Abundance of Soil mesofauna (top soil and subsoil) (per 100g of soil) Rainy season and Dry season

	Family	Scientific Name	TOP SOIL (0-15)			SUB-SOIL (15-30)			
			ONP Total	ORP Total	OOP Total	ONP Total	ORP Total	OOP Total	Sum
1	Rhabditida	Carnorhabditis elegans	(20)35	(33)30	(83)65	(42)40	(49)46	(100)81	(327)297
2	Nematoda	Acrobeloidea spp	14	32	74	27	56	76	279
3	Collembola	Tullbagia granilata	34	47	64	30	52	76	303
4	Termitidae	Microtermitae spp	(48)35	(55)37	(48)31	(65)37	(51)37	(49)35	(316)212
5	Oppiidae	Oniscus asellus	(50)37	(40)70	(36)70	(58)37	(40)65	(66)64	(290)343
6	Lumbricidae	Lumbricus rubellus	(27)30	(38)27	(48)35	(44)35	(50)31	(64)45	(271)203
7	Lumbricidae	Allolobophora trapezoids	(38) 31	(40)28	(32)21	(65)28	(51)35	(36)27	(262)170
8	Arthropoda	Spirosteptus spp	(49)39	(29)17	(31)56	(66)32	(48)20	(39)42	(262)206
9	Eudrilidae	Eudrilus eugeniae	52	49	36	57	53	63	310
10	Heteroderidae	Anguina spp	(31)46	(41)41	(41)33	(44)41	(78)66	(60)31	(295)258
11	Colpodidae	Colpoda steinii	(32)36	(40)30	(48)41	(5251	(62)27	(59)57	(293)242
12	Meloidogynidae	Meloidogyne spp	(24)44	(39)38	(51)33	(34)43	(52)42	(46)37	(246)237
13	Porcellionidae	Pocellio scober	69	36	51	79	44	52	331
14	Lumbricidae	Allolobophora coliginosa	51	34	43	32	44	52	256
15	Oribatida	Belbal spp	(15)37	(56)31	(17)19	(40)40	(50)24	(40)34	(218)185
16	Philopotamidae	Philopotamus montanus	(49)48	(27)32	(61)26	(55)53	(54)50	(58)34	(304)243
17	Oppiidae	Oniscus spp	(64)37	(52)70	(48)70	(55)37	(63)65	(61)64	(343)343
18	Tylenchida	Hirschmanniella spp	(66)62	(60)54	(50)24	(64)71	(68)64	(52)16	(360)291
19	Oppiidae	Oppiella spp	(55)28	(49)59	(37)66	(68)40	(51)58	(40)70	(300)321
20	Hymenoptera	Dorylus fimbriatus	(44)26	(49)16	(71)17	(50)43	(71)16	(73)21	(358)139
21	Hymenoptera	Epidamaeus spp	(39)41	(45)61	(49)61	(38)40	(47)61	(51)62	(269)326
22	Collembola	Fulsomia candida	(38)40	(44)59	(44)40	(52)55	(70)76	(62)58	(310)228
23	Glomeridae	Glomeris maginata	(57)22	(62)59	(64)34	(46)30	(67)58	(47)30	(343)233
24	Diptera	Tachina urcsine	(13)27	(55)45	(46)56	(10)33	(44)57	(27)51	(195)269
25	Lypusidae	Diurnea flagella	(51)58	(73)35	(34)31	(54)59	(64)36	(53)41	(329)260
26	Formicidae	Myrmicaris striata	59	67	28	36	73	26	289
27	Nematoda	Acanthamoeba pilyphages	46	32	46	52	43	51	270
28	Diplopoda	Bdellozonium spp	(62)24	(23)27	(25)39	(47)32	(24)31	(27)31	(208)184
29	Araneae	Chaetopeima spp	(35)21	(18)21	(36)11	(34)18	(29)33	(42)13	(194)117
			(1232)818	(1265)861	(1342)852	(1396)928	(1548)979	(1548)934	(8331)5372

ONP: Okomu National park, ORP: Okomu Rubber Plantation, OOP: Okomu Oil palm Plantation . Values in parenthesis are correspond rainy season values,

Table 3: Influence of seasons on soil mesofauna dominant species

S/N	Family	Scientific Name	Season Dry	Rainy
1	Lumbricidae	*Lumbricus rubellus*	*	*
2	Lumbricidae	*Allolobophora trapezoids*	*	*
3	Eudrilidae	*Eudrilus eugeniae*	Ab	**
4	Lumbricidae	*Allolobophora coliginosa*	*	*
5	Araneae	*Chaetopeima spp*	*	*
6	Arthropoda	*Spirosteptus spp*	*	*
7	Glomeridae	*Glomeris maginata*	Ab	**
8	Collembola	*Tullbagia granilata*	Ab	**
9	Collembola	*Fulsomia candida*	*	*
10	Diplopoda	*Bdellozonium spp*	*	*
11	Diptera	*Tachina urcsine*	*	*
12	Colpodidae	*Colpoda steinii*	**	Ab
13	Glomeridae	*Glomeris maginata*	**	Ab
14	Hymenoptera	*Epidamaeus spp*	Ab	**
15	Hymenoptera	*Dorylus fimbriatus*	**	Ab
16	Termitidae	*Microtermitae spp*	*	*
17	Colpodidae	*Colpoda spp*	Ab	**
18	Formicidae	*Dorylus fimbriatus*	Ab	**
19	Formicidae	*Myrmicaris striata*	Ab	**
20	Lepidoptera	*Diurnea flagella*	*	*
21	Oniscidae	*Oniscus asellus*	*	*
22	Porcellionidae	*Pocellio scober*	Ab	**
23	Nematoda	*Acrobeloidea spp*	Ab	**
24	Nematoda	*Acanthamoeba pilyphages*	Ab	**
25	Oribatida	*Belbal spp*	*	*
26	Rhabditida	*Carnorhabditis elegans*	*	*
27	Sacroptiformes	*Epidamaeus spp*	*	*
28	Oppiidae	*Oppiella spp*	**	Ab
29	Philopotamidae	*Philopotamus montanus*	*	*
30	Heteroderidae	*Anguina spp*	*	*
31	Meloidogynidae	*Meloidogyne spp*	*	*
32	Pratylenchidea	*Hirschmanniella spp*	*	*

**= Present of soil mesofauna species in two seasons, **= dominant of soil mesofauna species in one season, ab= absent of soil mesofauna species in one season*

Table 4: Effects of land use systems, seasons and depths on diversity and abundance of soil mesofauna species in the study area

Land Use Systems	Diversity	Abundance
ONP	3.23 ± 0.101^{a}	42.91 ± 4.239^{a}
ORP	3.20 ± 0.154^{a}	45.41 ± 5.736^{a}
OOP	3.18 ± 0.157^{a}	45.04 ± 6.430^{a}
P-Value	0.398	0.172
Seasons		
Dry Season	3.09 ± 0.062^{b}	41.03 ± 2.845^{b}
Rainy Season	3.32 ± 0.015^{a}	47.88 ± 4.699^{a}
P –Value	0.000	0.000
Depths		
Top-soil	3.19 ± 0.135^{a}	41.38 ± 3.321^{b}
Sub-soil	3.22 ± 0.131^{a}	47.53 ± 4.954^{a}
P-Value	0.287	0.001

Values followed by superscripts in the same columns are significantly ($p \leq 0.05$) different

The reasonably diverse plant canopy found on oil palm plantations (Foster *et al.,* 2011) supports this notion and agrees with the findings of Begum *et al.* (2009), who reported variations in soil mesofaunal diversity, abundance, and activities based on land use systems. It was observed in this study that less diverse litter in rubber and oil palm plantations might have attracted a greater abundance of soil mesofauna, consequently contributing to the higher diversity index. However, it is noteworthy that natural forests with higher soil water content, C:N concentrations. The carbon-to-nitrogen ratio is a key indicator of the nutrient balance in soil and organic matter, as litter amounts provide more favourable conditions for bacteria, thereby reinforcing the bacterial energy channel (Wardle *et al.,* 2004; Susanti *et al.,* 2005).

Seasonal Effects on Soil Mesofauna Diversity and Abundance

The results of this study also showed that the diversity and abundance of soil mesofauna in the study areas differed between the rainy and dry seasons. This observation is consistent with that of Manhes *et al.* (2013), who reported seasonal variations in microbial, herbivore, and predator populations within land use systems. Previous studies have shown a positive correlation between soil moisture and the population density of soil fauna (Tsaifouli *et al.,* 2005; Begum *et al.,* 2010; Zhang *et al.,* 2021). This relationship can be attributed to the crucial role of soil moisture in stimulating soil biological activity.

The seasonal variations in soil mesofaunal diversity and abundance observed in the study areas align with the findings of Kardol *et al.* (2011), who observed seasonal changes in soil arthropod communities. Specifically, forest ecosystems exhibit greater soil arthropod abundance during the rainy season than during the dry season (Wiwatwitaya and Takeda, 2004). Numerous studies have consistently highlighted soil moisture as the most significant environmental factor that determines the structure and function of soil faunal communities (Verhoef & van Selm, 1983; Moron-Rios *et al.,* 2010). Additionally, Wardle (2002) reported on the extinction of epigeic worm species, a decline in larger oligochaetes and Prostigmata mites, and the migration of enchytraeids to deeper soil, corroborating the variations in the diversity and abundance of soil mesofauna during different seasons observed in the present study.

Effect of Soil Depth on Soil Mesofauna Diversity and Abundance

An incremental shift in both mesofaunal diversity and abundance was observed as soil depth increased, with the highest species abundance recorded in the subsoil layer (15-30 cm) across all land use systems. The underlying cause of this phenomenon may be attributed to environmental factors, such as temperature and rainfall, which likely played a crucial role in influencing the distribution of the soil mesofaunal community along the soil depth gradient. This finding stands in contrast to prior reports by Fierer et al. (2003) and Fritze et al. (2000), who reported greater soil faunal abundance in the topsoil due to the presence of biomass on the forest floor and indicated that mesofauna thrived in minimally disturbed forest ecosystems (Adeduntan & Olusola, 2012). The observed downground migration of soil mesofauna to seek refuge in deeper layers during the dry season, as a response to decreased soil moisture in dry periods, suggests a survival strategy (Detsis, 2000; Briones et al., 1997; and Lavelle et al., 1997). Soil mesofauna have been recognized as excellent bioindicators that are particularly sensitive to environmental changes (Jucevica & Melecis, 2006; Xu et al., 2009). Previous research has indicated that various changing climatic factors, including solar radiation (Berthe et al. 2015), temperature (Bokhorst et al., 2008), precipitation (Frampton et al., 2000), and moisture (Kaneda & Kaneko, 2011; Chikoski et al., 2006; Frouz et al., 2021), influence soil mesofauna abundance (Peña-Peña &Irmler, 2016). According to Kardol et al., (2010), mesofauna are important bioindicators for assessing the impacts of climate change on terrestrial ecosystems due to their sensitivity to changes in the soil environment. The shift in mesofaunal diversity and abundance towards the subsoil observed in this study aligns with the findings of Aimée et al., (2015), who suggested that soil communities may adjust their distribution within the soil profile in response to climatic stress. For instance, during periods of suboptimal surface temperatures, they may move deeper into the soil profile.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the research findings revealed that the subsoil layer consistently exhibited greater soil mesofaunal diversity and abundance across various land use systems, with the Okomu Rubber Plantation showcasing the highest levels. The Okomu Oil Palm Plantation followed closely, while Okomu National Park recorded the lowest diversity and abundance. Additionally, seasonal variations significantly influenced these patterns, as the rainy season demonstrated elevated soil mesofaunal diversity. Therefore, future research should investigate the specific factors driving these trends to inform targeted conservation and management strategies for sustainable soil ecosystems.

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Authors' Contribution

OJA managed data collection, interpretation of data, literature searching, writing the manuscript. SAA & OTA managed the developmemet of methodology, and revised the manuscript. All authors read and approved the final manuscript.

Ethical Statement

Not applicable.

REFERENCES

Achat, DL., Deleuze, C., Landmann G., Pousse N., Ranger J. & Augusto L. (2015). Quantifying consequences of removing harvesting residues on forest soil and tree growth: a meta analysis. *Forest Ecology and Management* 348: 124-141. https://doi.org/10.1016/j.foreco.2015.03.042

Adeduntan SA. & Olusola JA. (2012). Comparative Survey of Litter Arthropods and Soil Mesofauna in Natural Forest and Plantation Akure Forest Reserve (Aponmu). *International Journal of Agriculture and Forestry,* 2(1): 63-71. https://doi.org/10.5923/j.ijaf.20120201.11

Adeduntan, SA. (2009). Diversity and abundance of soil mesofauna and microbial population in South-Western Nigeria. *African Journal of Plant Science*, 3(9), 210-216.

Aimée, TC., Maja, KS., Jeremiah, AH., Gregory, SN., Jessica, AMM., Melissa, AC., Leigh, CM. & Courtney, MP. (2015). Direct and indirect effects of climate change on soil microbial and soil microbial plant interactions: What lies ahead? 6, (8): 1-21. https://doi.org/10.1890/ES15-00217.1

Balasubramanian, A. (2017). Soil microorganisms. Univ. Mysore, 5-22.

Battirola LD., Adis J., Marques MI. & Silva FHO. (2007). The arthropod community associated with the canopy of Attalea phalerata Mart. (Araceae) during the flood period of the Pantanal of Poconé, MT. *Neotropical Entomology* 36 (5): 640-651. https://doi.org/10.1590/S1519-566X2007000500002

Begum F., Bajracharya, RM., Sharma, S. & Situala, B. K. (2009). Land use effects on soil quality Indicators in mid-hills of Central Nepal. In*: International Conference Proceeding of "Emerging Technologies in Environmental Sciences and Engineering*". India: Aligarh Muslim University; p. 488–495

Begum, F., Bajracharya, RM., Sharma, S. & Situala, BK. (2010). Influence of slope aspect on soil physic-chemical and biological properties in the mid hill of central Nepal. *International Journal of Sustainable Devevelopment and World Ecology*. 17 (5) : 438–

443. https://doi.org/10.1080/13504509.2010.499034

Berthe, SCF., Derocles, SAP., Lunt, DH., Kimball, BA. & Evans, DM. (2015) Simulated climate-warming increases Coleoptera activity-densities and reduces community diversity in a cereal crop. *Agricultural Ecosystem and the Environment*, 210, 11–14. https://doi.org/10.1016/j.agee.2015.05.001

Bokhorst, S., Huiskes, AH., Convey, P., Van Bodegom, PM. & Aerts R. (2008). Climate change effects on soil arthropod communities from the Falkland Islands and the Maritime Antarctic. *Soil Biology and Biochemestry*. 40 (7): 1547–1556. https://doi.org/10.1016/j.soilbio.2008.01.017

Bradshaw, CJA., Sohdi, NS. & Brook, BW. (2009). Tropical turmoil: a biodiversity tragedy in progress. *Frontiers in Ecology and the Environment* 7(2): 79-87. https://doi.org/10.1890/070193

Briones, MJI., Ineson, P. & Piearce, TG. (1997). Effects of climate change on soil fauna; responses of enchytraeids, Diptera larvae and tardigrades in a transplant experiment. *Applied Soil Ecology* 6 (2): 117–134. https://doi.org/10.1016/S0929-1393(97)00004-8

Chikoski, JM., Ferguson, SH. & Meyer, L. (2006). Effects of water addition on soil arthropods and soil characteristics in a precipitation-limited environment. *Acta Oecologica* 30(2): 203–211. https://doi.org/10.1016/j.actao.2006.04.005

Choi, W., Moorhead, DL., Neher, DA. & Ryoo, M. (2006). A modelling study of soil temperature and moisture effects on population dynamics of Paronychiurus kimi (Collembola: Onychyuridae). *Biology and Fertility of Soils* 43: 69-75. https://doi.org/10.1007/s00374-005-0062-5

Costa, J., Oliveira, RS., Tiago, I., Ma, Y., Galhano, C., Freitas, H. & Castro, P. (2018). Soil microorganisms. *Advances in plant ecophysiology techniques*, 457-482. https://doi.org/10.1007/978-3-319-93233-0_27

Crespo-Pérez, V., Kazakou, E., Roubik, DW. & Cárdenas, RE. (2020). The importance of insects on land and in water: a tropical view. *Current opinion in insect science*, 40, 31-38. https://doi.org/10.1016/j.cois.2020.05.016

Dagallier, LPM., Janssens, SB., Dauby, G., Blach Overgaard, A., Mackinder, BA., Droissart, V. & Couvreur, T. L. (2020). Cradles and museums of generic plant diversity across tropical Africa. *New Phytologist*, 225 (5): 2196-2213. https://doi.org/10.1111/nph.16293

Detsis, V. (2000). Vertical distribution of Collembola in deciduous forests under Mediterranean climatic conditions. *Belgian Journal of Zoology*. 130 (Suppl.), 55–59.

Dijkstra, FA, Carrillo Y, Pendall, E. & Morgan, JA. (2013). Rhizosphere priming: a nutrient perspective. *Frontiers in Microbiology*. 4, 216. https://doi.org/10.3389/fmicb.2013.00216

Fierer ,N., Schimel J. & Holden P. (2003). Variations in microbial community composition through two soil depth profiles. *Soil Biol. Biochem*., 35 (1): 167–176. https://doi.org/10.1016/S0038-0717(02)00251-1.

Foster, WA., Snaddon, JL., Turner, EC., Fayle, TM., Cockerill, TD., Farnon Ellwood, MD., Broad, GR., Chung, AYC., Eggleton, P., Khen, CV. & Yusah, KM. (2011). Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. *Philos. Trans. R. Soc. B Biol. Sci.* 366 (1582): 3277–3291. https://doi.org/10.1098/rstb.2011.0041

Frampton, GK., Van Den Brink, PJ. & Gould, PJ. (2000). Effects of spring drought and irrigation on farmland arthropods in southern Britain. *J. Appl. Ecol*. 37, 865–883. https://www.jstor.org/stable/2655931

Fritz, A., Percy, C., Jack, A., Sobin, L., Parkin, M. & Whelan, S. (2000). International Classification of Diseases for Oncology, 3rd edn. *WHO*, Geneva, Switzerland.

Frouz, J. (2018). Effects of soil macro-and mesofauna on litter decomposition and soil organic matter stabilization. *Geoderma*, 332, 161-172. https://doi.org/10.1016/j.geoderma.2017.08.039

Giam, X. (2017). Global biodiversity loss from tropical deforestation. Proceedings of the National Academy of Sciences, 114 (23): 5775-5777. https://doi.org/10.1073/pnas.1706264114

Hendrix, PF. (2000). Soil fauna. In: Sumner, M.E. Handbook of Soil Science. CRC Press, Boca Raton, FL, USA.

Javed, A., Ali, E., Afzal, K B., Osman, A. & Riaz, S. (2022). Soil fertility: Factors affecting soil fertility, and biodiversity responsible for soil fertility. *International Journal of Plant, Animal and Environmental Sciences*, 12 (1): 21-33.

Jucevica E. & Melecis V. (2006). Global warming affect Collembola community: A long-term study. *Pedobiologia* 50 (2): 177-184 . https://doi.org/10.1016/j.pedobi.2005.10.006

Kaneda S. & Kaneko N. (2011). Influence of Collembola on nitrogen mineralization varies with soil moisture content. *Soil Sci. Plant Nutrient, 57* (1): 40–49. https://doi.org/10.1080/00380768.2010.551107

Kardol, P., Cregger MA., Campany C. & Aimee TC. (2010). Soil ecosystem functioning under climate change: Plant species and community effects. *Ecology*, 91(3), 767-781. https://doi.org/10.1890/09-0135.1

Kardol P., Reynolds WN., Norby R.J. & Classen AT. (2011). Effects of climate change on soil microarthropod abundance and community structure. *Applied Soil Ecology*, 47 (1): 37–44. https://doi.org/10.1016/j.apsoil.2010.11.001

Kent M. & Coker P. (1992). Vegetation description and analysis. A practical approach, Belhaven Press London 363 pp.

Khatoon, H., Solanki, P., Narayan, M., Tewari, L., Rai, J. & Hina Khatoon, C. (2017). Role of microbes in organic carbon decomposition and maintenance of soil ecosystem. *International Journal of Chemical Studies*, 5 (6), 1648-1656.

KrashevskaV., Klarner B., Widyastuti R., Maraun M. & Scheu S. (2015). Impact of tropical lowland rainforest conversion into rubber and oil palm plantations on soil microbial communities. *Biology and Fertility of Soils*, 51 (6): 697– 705. https://doi.org/10.1007/s00374-015-1021-4

Lavelle P., Bignell D., Lepage M., Wolters V., Roger P. & Ineson P. (1997). Soil function in a changing world: the role of invertebrate ecosystem engineers. *Eur. J. Soil Biol*.33 (4): 159-193

Manhães CMC., Gama-Rodrigues EF., Moço MK S. & Gama-Rodrigues AC. (2013). “Meso- and Macrofauna in the Soil and Litter of Leguminous Trees in a Degraded Pastures in Brazil.” *Agroforestry Systems* 87 (5): 993-1004.

Moço MKS., Correia MEF., Rodrigues ACG. & Rodrigues EFG. (2005). Characterization of soil fauna in different vegetation covers in the northern Fluminense region (RJ). Revista Brasileira de Ciência do Solo 29 (4): 555-564. https://doi.org/10.1590/S0100-06832005000400008

Moreira, F. M. S., Siqueira, J. O. & Brussaard, L. (2008). Soil biodiversity in Brazilian ecosystems. *Federal University Lavras*, Lavras, 768.

Morón-Ríos, A., Rodríguez, MÁ., Pérez-Camacho, L. & Rebollo, S. (2010). Effects of seasonal grazing and precipitation regime on the soil macroinvertebrates of a Mediterranean old-field. *European Journal of Soil Biology*, 46 (2): 91-96. https://doi.org/10.1016/j.ejsobi.2009.12.008

Myers N., Mittermeier RA., Mittermeier CG., Da Fonseca GAB., & Kent J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403 (6772): 853-858.

Neera Garg, NG. & Shikha Chandel, SC. (2010). Arbuscular mycorrhizal networks: *process and functions*. A review. volume 2, 907-930. https://doi.org/10.1051/agro/2009054

Okomu National Park. (2010). NigeriaNational Park Service. Retrieved 4 November

Peña-Peña. & Irmler U. (2016). Moisture seasonality, soil fauna, litter quality and land use as drivers of decomposition in Cerrado soils in SE-Mato Grosso, Brazil. Applied Soil Ecology , 107, 124–133. https://doi.org/10.1016/j.apsoil.2016.05.007

Pollierer, MM. & Scheu, S. (2017). Driving factors and temporal fluctuation of Collembola communities and reproductive mode across forest types and regions. *Ecology and Evolution*, 7(12): 4390-4403. https://doi.org/10.1002/ece3.3035

Rosa MG, Klauberg Filho O, Bartz, M.LC, Mafra AL, Sousa JPFA. & Baretta D (2015). Soil macrofauna and physical and chemical properties under soil management systems in the Santa Catarina highlands, Brazil. RevistaBrasileira de Ciência do Solo 39 (6): 1544-1553. http://dx.doi.org/10.1590/01000683rbcs20150033

Rousseau, L., Venier, L., Hazlett, P., Fleming, R., Morris, D. & Handa, IT. (2018). Forest floor mesofauna communities respond to a gradient of biomass removal and soil disturbance in a boreal jack pine (Pinus banksiana) stand of northeastern Ontario (Canada). *Forest Ecology and Management*, 407, 155-165. https://doi.org/10.1016/j.foreco.2017.08.054

Soladoye, M.O. & Oni, O. (2000). Biodiversity studies at Okomu Forest Reserve in Edo State. A report of the National Agricultural Research Project. 128.

Susanti, W, Pollierer M, Widyastuti R, Scheu S. & Potapov A. (2019). Conversion of rainforest to oil palm and rubber plantations alters energy channels in soil food webs. *Ecology and Evolution.* 9 (90): 27–39. https://doi.org/10.1002/ece3.5449

Tan, B., Yin, R., Zhang, J., Xu, Z., Liu, Y., He, S. & Peng, C. (2021). Temperature and moisture modulate the contribution of soil fauna to litter decomposition via different pathways. *Ecosystems*, 24, 1142-1156. https://doi.org/10.1007/s10021-020-00573-w

Tsiafouli MA., Kallimanis AS., Katana E., Stamou GP. & Sgardelis SP. (2005). Responses of soil micro arthropods to experimental short term manipulations of soil moisture. *Applied Soil Ecology*, 29 (1): 17–26. https://doi.org/10.1016/j.apsoil.2004.10.002

Van Straaten O., Corre MD., Wolf K., Tchienkoua M., Cuellar E., Matthews RB. & Veldkamp, E. (2015). Conversion of lowland tropical forests to tree cash crop plantations loses up to one half of stored soil organic carbon. *Proceedings of the National Academy of Sciences of the United States of America*, 112 (32): 9956– 9960. https://doi.org/10.1073/pnas.1504628112

Verhoef A. & van Selm AJ. (1983) Distribution and population dynamics of Collembola in relation to soil moisture. *Holarctic Ecology*, 6 (4): 387–394. https://doi.org/10.1111/j.1600-0587.1983.tb01234.x

Wardle DA. (2002). Communities and Ecosystems: *Linking the Aboveground and Belowground Components.* Princeton University Press, Princeton, New Jersey, 408.

Wardle DA., Bardgett RD., Klironomos JN., Setala H., van der Putten WH. & Wall DH. (2004) Ecological linkages between aboveground and belowground biota. *Science,* 304 (5677): 1629–1633. https://doi.org/10.1126/science.1094875

Winda, IS., Melanie, MP., Rahayu, W., Stefan, S. & Anton, P. (2019). Conversion of rainforest to oil palm and rubber plantations alters energy channels in soil food webs; *Academic Practice in Ecology and Evolution*. 9(16): 9027-9039. https://doi.org/10.1002/ece3.5449

Wiwatwitaya D., & Takeda H. (2005). Seasonal changes in soil arthropod abundance in the dry evergreen forest of north–east Thailand, with special reference to collembolan communities. *Ecological Research*, 20, 59–70. https://doi.org/10.1007/s11284-004-0013-x

Xu, GL., Schleppi P., Li MH., & Fu SL. (2009). Negative responses of Collembola in a forest soil (Alptal, Switzerland) under experimentally increased and deposition. *Environmental Pollution* 157 (7): 2030-2036. https://doi.org/10.1016/j.envpol.2009.02.026