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Analysis of earthworm ecology in Lamto (Côte d'Ivoire)

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Abstract

This study examined earthworm ecology in the Lamto Reserve (Côte d'Ivoire) in relation to vegetation cover (wooded savanna, grassy savanna, and forest) and soil depth (0–10 cm, 10–20 cm, and 20–30 cm). Sampling was carried out using the monolith method and enabled the identification of nine species distributed among three ecological groups: epigeic, endogeic, and anecic, which were differentiated by their size and the position of their clitellum. Species richness was highest in the surface layer (0–10 cm), with a slight dominance in the forest, where nine species were recorded. Mean earthworm density varied significantly, with the highest values recorded in the forest. The species *Stuhlmannia zielae* was dominant there, with 433.6 ± 188.86 individuals/m^2. The biomass of *Millsonia omodeoi* was higher in the wooded savanna (70.50 ± 32.44 g/m^2). Analysis of variance (ANOVA) showed significant effects of vegetation type, soil depth, and their interaction on density and biomass ($p < 0.05$). The post hoc Tukey test indicated that the surface layer differed significantly in terms of density and biomass between the forest and the wooded savanna. These results demonstrated that earthworms were strongly influenced by environmental conditions such as soil moisture, organic matter availability, and soil structure.

Keywords: Earthworms; Species richness; Density; Biomass; Tukey test; Lamto

1 Introduction

Earthworms were a key group within the soil macrofauna. They were divided into different ecological categories, including epigeic, endogeic, and anecic species. Each group occupied a specific niche and had particular requirements in terms of substrate and environmental conditions (Bouché, 1972; Lavelle et al., 1998). Earthworms played a fundamental role in the functioning of terrestrial ecosystems (Blouin et al., 2013; Schön et al., 2021). As ecosystem engineers, they actively contributed to the decomposition of organic matter, soil structuring, and nutrient cycling. Their biological activities promoted the mineralization of organic matter and the release of essential nutrients such as nitrogen and phosphorus (Scheu, 2022). Consequently, they enhanced soil fertility and contributed to increased agricultural productivity (Wall et al., 2015).However, their species diversity and population density were strongly influenced by environmental conditions, including vegetation cover, soil moisture, organic matter content, and the intensity of anthropogenic disturbances (Blouin et al., 2013; Schön et al., 2021). Their sensitivity to environmental changes, combined with their crucial functional role, made them valuable indicators for assessing the health of terrestrial ecosystems. Furthermore, in the context of organic waste valorisation, earthworms were widely used in vermicomposting. Certain epigeic species were particularly well suited to these practices due to their high reproductive capacity and their ability to rapidly convert organic waste into vermicompost. This vermicompost was a nutrient-rich organic amendment that improved soil structure and enhanced nutrient availability for plants. In Côte d'Ivoire, where climatic conditions were predominantly tropical and organic waste production was substantial, the development of

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earthworm farming represented a promising and sustainable solution for waste management and soil fertility improvement. represents both an ecological and economic opportunity. However, the success of this activity depends heavily on the choice of substrate, which must meet the ecological requirements of the species used while also being locally available and economically viable. Thus, analyzing earthworm ecology appears to be an essential step in guiding the selection of earthworms and substrates best suited to their farming.

2 Materials and methods

2.1 Presentation of the study site

The Lamto Ecological Station, founded in 1962 by Maxime Lamotte and Jean-Luc Tournier, was dedicated to the study of tropical ecosystems. Located south of the Baoulé "V" (a region in Côte d'Ivoire), in the Taabo department, approximately 160 km from Abidjan, it covered 2,617 hectares at a latitude of 6°13′ North and 5°03′ West. It was a major research site for tropical savannas (N'Goran & Andon, 2024). The climate was subequatorial, with an average annual rainfall ranging between 1,200 and 1,300 mm. It was characterized by four seasons: a long rainy season (March–July), a short dry season (August), a short rainy season (September–November), and a long dry season from December to February (Touré, 2010). The vegetation was characterized by a mosaic of grassy and wooded savannas, interspersed with gallery forests along watercourses (Lamotte, 1975). The terrain was gently undulating, consisting of low plateaus incised by depressions (Riou, 1974). The hydrological network comprised small temporary and permanent streams connected to the Bandama River basin (Delmas, 1967). The soils were dominated by tropical ferruginous soils developed on granitic substrates and by vertisols located on amphibolites in gently sloping areas (Riou, 1974). They varied according to topography: they were sandy and nutrient-poor on the plateaus, more silty and prone to erosion on the slopes, and hydromorphic at the bottom of the slopes (Delmas, 1967)

2.2 Equipment

The biological material used in this study consisted of earthworms collected from three distinct ecological facies: shrub savanna, grass savanna, and forest. The technical equipment used in this study comprised several specific instruments, each serving a precise function in the earthworm sampling and analysis process. A machete was used to clear the vegetation covering the monoliths, each with an area of approximately 1 m^2. A GPS (Global Positioning System) was used to accurately record the geographic coordinates of the four points delimiting each sampling plot, thus facilitating their location during future follow-up campaigns. The monoliths were delimited using a 50 cm × 50 cm grid, while a pickaxe was used to excavate the four sides of the soil blocks for their extraction. Earthworms were carefully collected using forceps and then placed individually in jars. These containers were labelled with an indelible marker, including essential information such as the collection date, location, monolith number, and corresponding ecological stratum. The specimens were then fixed in a 4% formalin solution to preserve their morphology for subsequent identification. This identification was carried out using a binocular microscope, referring to the earthworm identification guide developed by Tondoh (2006).

2.3 Methods

2.3.1 Choice of study site

The BIOTA-west (Biodiversity and Transect Analysis – West) project, conducted from 2000 to 2010 in Côte d'Ivoire, aimed at the conservation and sustainable use of biodiversity (BIOTA, 2010). Within this framework, the Lamto Scientific Reserve, managed by Nangui Abrogoua University, was subdivided into several monitoring areas, including the northern one selected for this study (IRD Data verse). This monitoring area (1 km^2) comprises several habitat types, including grassland savanna, wooded savanna, and forest. Within each habitat type, five plots were randomly selected without replacement. The plots were georeference dusing GPS and marked on the ground. In each plot, five monoliths (50 × 50 × 30 cm) were sampled (four at the corners and one in the center), for a total of 25 monoliths per habitat type. Sampling was carried out by direct manual sorting according to the methods described by Vincent (1969), Lavelle (1978), and Tondoh (1998). Prior clearing of the soil and the creation of a 0-30 cm deep ditch helped limit earthworm escape and facilitate their collection by strata: stratum 1 (0-10 cm), stratum 2 (10-20 cm), and stratum 3 (20-30 cm). Earthworms were collected by stratum, picked using forceps, and then preserved in jars with 4% formalin, labelled with the vegetation type and stratum. They were then transported to the laboratory for morphological identification based primarily on the size and position of the clitellum. The formalin stiffened them to facilitate this identification Tondoh, 1998).

2.3.2 Identification of earthworms

The ecological categories of earthworms were epigeic, endogeic, and anecic. Individuals exhibiting all adult characteristics were separated into these three ecological groups. An adult was identified by the presence of a well-developed clitellum. The morphological characteristics selected for observation were the size and position of the clitellum. The choice of these criteria was essential because they were easy to observe, reliable, and highly informative from both taxonomic and biological perspectives. The literature provided guidance in this regard (Lavelle, 1978; Edwards & Bohlen, 1996). Individuals from each category were observed under a binocular microscope in Petri dishes lined with moistened paper. Epigeic earthworms had an average length of 1–5 cm, endogeic earthworms ranged from 6–20 cm, and anecic earthworms ranged from 10–110 cm (Vigot and Cluzeau, 2014). Based on this distribution, species were identified according to the position of their clitellum. Located in the first third of the earthworm's body, the clitellum was a thickened glandular area involved in reproduction. In epigeic earthworms, the clitellum was poorly developed, thin, small, and fine. In endogeic earthworms, it was moderately developed and encircled the body. In anecic earthworms, it was more developed and ridged, also encircling the body. The literature had previously classified the clitellum according to its position on the body segments of earthworms. These observations were made possible by the systematic work of Lavelle (1978) and Lavelle and Spain (2001). Furthermore, earthworms were counted by species to determine their density by stratum and facies. They were then weighed to estimate their biomass.

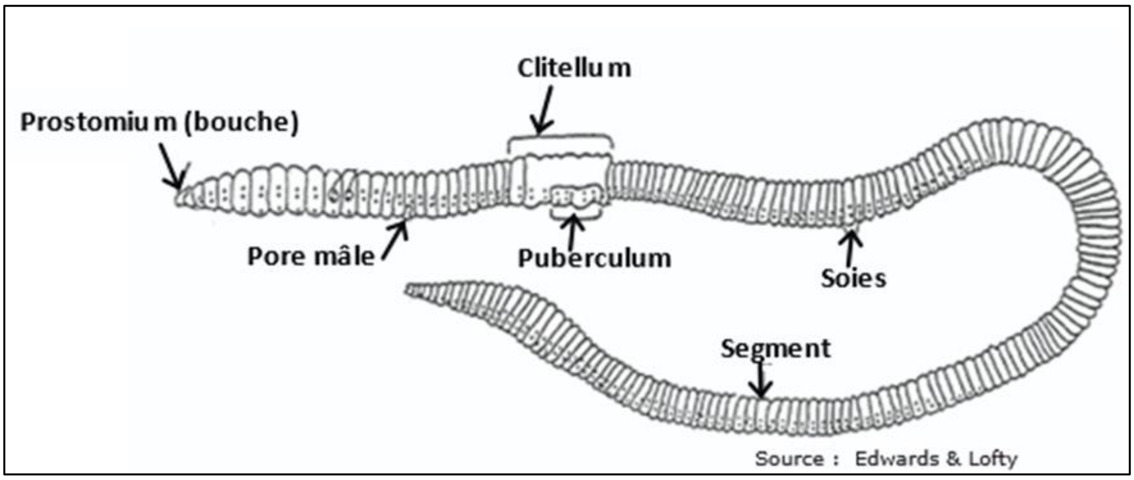

Figure 1 Morphology of an earthworm (Edwards & Lofty, 1972)

2.3.3 Determination of the species richness of the sampled worms

Species richness was defined as the number of different earthworm species present in a given ecosystem. Earthworm identification in the laboratory allowed the total number of species to be counted per facies and stratum within the sampling area. Species richness was considered an indicator of environmental biodiversity: the higher it was, the more balanced and healthy the environment was assumed to be. Furthermore, ecological functions such as soil fertility, soil aeration, and the decomposition of organic matter were considered more efficient in environments with higher species richness. The method used consisted of manual sorting following species identification.

$$S = \text{number of species}$$

Where:

- SSS = species richness
- number of species\text{number of species}number of species = total count of different species present in a given area or sample

2.3.4 Determination of the density of sampled worms

Earthworm density was defined as the total number of individuals per unit area. In soil studies, it was generally expressed as the number of individuals per square meter (ind/m^2). It was determined by stratum and facies within the sampling area. It was used to assess soil fertility. A high earthworm density indicated that the soil was rich in organic matter and therefore productive. Furthermore, it allowed for the evaluation of the soil's biological quality.

A low earthworm population indicated that the soil was degraded due to pollution associated with the inappropriate use of fertilizers and pesticides, the disposal of toxic substances into ecosystems, or other harmful activities. It was calculated using the following formula:

$$D=A/N$$

Where:

- D= earthworm density (individuals per square meter, ind/m^2)
- N= number of earthworms collected
- A= area sampled (in m^2)

2.3.5 Determination of the biomass of the sampled worms

Earthworm biomass was defined as the total mass of all earthworms present in a given environment. It was generally expressed in grams per square meter (g/m^2) or kilograms per hectare (kg/ha). High earthworm biomass generally indicated rich and healthy soil. Earthworms contributed to humus formation, thereby making the soil fertile and productive. Furthermore, high biomass indicated a significant contribution to natural cycles. Biomass also helped identify the most favorable substrates for earthworm growth. It was calculated using the following formula:

$$B=\sum mi/A$$

Where:

- m= mass of an individual earthworm
- A = sampled area (m^2)
- Result is expressed as g/m^2 or kg/m^2

2.3.6 Data Analysis

This study used two types of variables: the dependent variable (quantitative), which was what was measured (earthworm density and biomass), and the independent variable (qualitative), represented by habitat types (forest, wooded savanna, and grassland). An analysis of variance (ANOVA) was performed using R software to compare earthworm density and biomass between habitat types and strata (Raymondau, 2011). The chi-square (χ^2) test, applied to species richness as a function of habitat type and strata, allowed the distribution of species among the different studied environments to be assessed. Tukey's test was used to compare variability between habitat types and strata. The probability that the observed results were due to chance led to two interpretations in both tests: $p < 0.05$ indicated a significant difference, whereas $p > 0.05$ indicated no significant difference. The letters (a, b, ab) were used to compare facies (SA, SH, F) within the same stratum. The same letter indicated no significant difference, while different letters indicated a significant difference.

3 Results

3.1 Variability of identified species according to the position of the clitellum

At the level of Table I, the first group corresponded to species with an anterior clitellum (segments 13 to 18), including *Dichogaster agilis, Dichogaster saliens,* and *Hyperiodrilus africanus*. In these species, the clitellum was located relatively close to the anterior end of the body. The second group consisted of species with an intermediate clitellum (segments 17 to 20), notably *Dichogaster baeri, Scolecillus compositus*, and *Agastrodrilus sp*. These species exhibited intermediate characteristics, both morphologically and ecologically. Finally, the third group comprised species with a posterior clitellum (segments 19 to 25), including *Stuhlmannia zielae, Stuhlmannia palustris,* and *Millsonia omodeoi*. In these worms, the clitellum was located farther from the anterior region.

Table 1 Position of the clitellum of the species

Species	Position of the clitellum (segments)		
	Min	**Max**	**Standard deviation (σ)**
Dichogaster agilis(Epige)	13	20	3.5
Dichogaster baeri(Epige)	14	20	3
Dichogaster saliens(Epige)	13	19	3
Stuhlmannia zielae (Endogeous)	15	23	4
Stuhlmannia palustris (Endogeous)	15	24	4.5
Millsonia omodeoi (Endogeous)	15	25	5
Agastrodrilus sp. (Endogeous)	14	22	4
Scolecillus compositus(Anecic)	14	22	4
Hyperiodrilus africanus(Anecic)	13	18	2.5

3.2 Species richness by facies and strata

The species richness of earthworms by stratum and facies, in Table II, highlighted a clear vertical organization of species. At the level of Table II, Stratum 1 (0–10 cm), corresponding to the surface layer of the soil, exhibited the highest species richness, with 8 species present in each facies (wooded savanna, grassy savanna, and forest). This stratum primarily hosted shallow epigeal and endogeal species, such as *Dichogaster agilis, Dichogaster baeri, Dichogaster saliens, Stuhlmannia zielae, and Scolecillus compositus,* which exploited the abundant surface organic matter for food and reproduction. Stratum 2 (10–20 cm) showed lower richness, with only 4 species in the savannas and 7 species in the forest. Some surface species, such as *Dichogaster agilis, Dichogaster baeri*, and *Dichogaster saliens*, were absent from this intermediate savanna stratum, while the forest maintained higher diversity. Stratum 3 (20–30 cm), corresponding to the deeper layers, saw species richness stabilize at 5 species in all facies. Only the species best adapted to deep strata, such as *Stuhlmannia zielae, Stuhlmannia palustris, Agastrodrilus* sp., and *Millsonia omodeoi*, persisted, while epigeic and endogeic surface worms disappeared.

Table 2 Earthworm species richness by stratum

Species	Layer 1			Layer 2			Layer 3		
	ITS	**SH**	**F**	**ITS**	**SH**	**F**	**ITS**	**SH**	**F**
Dichogaster agilis(Epige)	+	+	+	-	-	+	-	-	+
Dichogaster baeri(Epige)	+	+	+	-	-	-	-	-	-
Dichogaster saliens(Epige)	+	+	+	-	-	+	+	-	-
Stuhlmannia zielae(Endogeous)	+	+	+	+	+	+	+	+	+
Millsonia omodeoi(Endogeous)	+	+	+	-	+	+	+	+	-
Stuhlmannia palustris(Endogeous)	+	+	+	+	+	+	+	+	+
Agastrodrilus sp.(Endogeous)	+	+	+	+	+	+	+	+	+
Scolecillus compositus(Anecic)	+	+	+	+	+	+	-	+	+
Hyperiodrilus africanus(Anecic)	-	-	-	-	-	+		-	-
Total Cash	8	8	8	4	4	7	5	5	5

NB +: present, SA: Wooded Savannah, SH: Grassy Savannah, F: Forest -: absent

3.3 Earthworm density by facies and strata

Earthworm density, as shown in Table III, decreased progressively with soil depth. It was highest in the surface layer (0–10 cm), with 32.9 ± 12.4 individuals/m² in wooded savanna, 24-± 14.4 individuals/m² in grassy savanna, and 64 ± 29.9 individuals/m² in forest. It then decreased in layer 2 (10–20 cm) and became very low in layer 3 (20–30 cm), regardless of the soil type. The surface layer was largely dominated by *Stuhlmannia zielae*, which was particularly abundant in forest (433.6 ± 188.86 individuals/m²). This species remained dominant in stratum 2, particularly in wooded savanna, while in deeper layers (stratum 3), densities were very low, with occasional dominance of *Agastrodrilus sp*. in grassy savanna. Two-way analysis of variance revealed a significant effect of facies and stratum on density ($p < 0.05$). Tukey's test showed that the surface stratum differed significantly from the deeper strata, and that forests exhibited higher densities than savannas. The facies × stratum interaction was also significant, indicating a high concentration of worms at the surface, especially in forests.

Table 3 Density (individuals/m²) of species by stratum and facies

	STRATE 1 (S1)			STRATE 2 (S2)			STRATE 3 (S3)		
Species	**ITS**	**SH**	**F**	**ITS**	**SH**	**F**	**ITS**	**SH**	**F**
Dichogaster agilis	4±2.52 a	5.6±5.98 a	12±8.76 a	0	0	0.4±0.48 a	10	0	0.2 ± 0.4 a
Dichogaster baeri	4±2.52 a	14.4 ± 9.32 b	8.8±5.30 ab	0	0	0	0.2 ± 0.4 a	0	0
Dichogaster saliens	19.2±15.05 a	6.4±7.41 a	19.2±9.66 a	23.2 ± 42.51 a	0	2±2.09 a	6±11.02 a	0.2 ± 0.4 a	0
Stuhlmannia zielae	169.6±41.92 b	108.8±56.70 b	433.6±188.86 a	98.4±43.71 a	15.2 ± 10.64 b	24.2 ± 13.01 b	11.6±16.66 a	4±5.09 a	3.6±1.85 a
Millsonia omodeoi	40±16.58 a	42.4±18.34 a	0.8 ± 11.14 b	4±4.38 a	2.8±2.78 a	0.8±0.74 a	3.6±6.24 a	1.4±1.49 a	0
Stuhlmannia palustris	13.6±9.66 a	6.4 ± 8.23 a	17.6±1.61 a	2.4±4.8 a	0.6±0.8 a	3.2 ± 2.03 a	0.8±0.97 a	0.2 ± 0.4 a	0.8±1.16 a
Agastrodrilus sp	7.2 ± 8.90 a	4.8±4.66 a	1.6±12.02 a	8±7.15 a	0.4±0.48 a	1.2 ± 1.46 a	2.4 ± 4.31 a	0.6±0.48 a	0.2 ± 0.4 a
scolecillus compositus	5.6±1.95 a	3.2 ± 4.6 a	18.4 ± 9.66 b	0.8±1.6 a	0.4±0.8 a	1.8±2.63 a	0.4±0.8 a	0.4±0.8 a	0.4±0.48 a
Hyperiodrilus africanus	0	0	0	0	0	0.2 ± 0.4 a	0	0	0

SA: Wooded Savannah, SH: Grassy Savannah, F: Forest

3.3 Biomasses earthworms by layer

Earthworm biomass, as shown in Table IV, decreased markedly with soil depth, reaching a maximum in the surface layer (0–10 cm): 7.10 ± 3.86 g/m² in wooded savanna, 4.92 ± 2.35 g/m² in grassy savanna, and 3.38 ± 2 g/m² in forest. It declined in the middle layer (10–20 cm) and became very low in the deep layer (20–30 cm). The surface layer was largely dominated by Millsonia omodeoi in wooded savanna (48.48 ± 24.90 g/m²), while Dichogaster saliens stood out in the middle layer and Agastrodrilus sp. in the deeper layer of grassy savanna. The two-way ANOVA showed a significant effect of soil type and stratum on biomass ($p < 0.05$). Tukey's test indicated that the surface stratum differed significantly from the deep strata, and that the facies × stratum combinations exhibited high biomasses, confirming the concentration of species at the surface, particularly in savannah and forest.

Table 4 Biomasses earthworms by facies and stratum (g/m2)

Species	SA (S1)	SH (S1)	F (S1)	SA (S2)	SH (S2)	F (S2)	SA (S3)	SH (S3)	F (S3)
Dichogaster agilis	0.58±0.46 a	0.84±0.97 a	1.73±1.57 a	0	0	0.07±0.11 a	0	0	0
Dichogaster baeri	0.79±0.63 a	1.58±1.07 a	1.69±1 a	0	0	0	0	0	0.20 ± 0.41 a
Dichogaster saliens	0.19±0.08 a	0.37±0.23 a	1.22 ± 1.16 a	16.57±23.76 a	0	0.09±0.09 a	1.89±3.79 a	0	0
Stuhlmannia zielae	4.93 ± 2.60 b	4.54 ± 2.22 b	19.08±6.61 a	6.63 ± 2.56 a	3.01 ± 1.43 b	5.67±6.34 ab	0.36±0.27 a	0.82±1.03 a	1.74±2.35 a
Millsonia omodeoi	48.48 ± 24.90 a	29.47±11.42 a	0.14 ± 0.29 b	0	16.17±26.95 a	5.78±11.57 a	8.43 ± 10.4 a	8.66 ± 10.03 a	0.26±0.52 a
Stuhlmannia palustris	0.21 ± 0.27 a	0.56±0.72 a	0.23 ± 0.11 a	0.45±0.90 a	0.14±0.18 a	0.32 ± 0.25 a	0	0	0.10±0.21 a
Agastrodrilus sp	1.50±1.84 a	1.95±2.12 a	0.48±0.97 a	0.47±0.59 a	0.87±1.36 a	0.58±1.17 a	1.94±3.89 a	7.73 ± 5.43 b	0.06±0.13 a
scolecillus compositus	0.10±0.09 a	0.04±0.05 a	2.49 ± 4.48 b	0.02 ± 0.03 a	0.01±0.03 a	0.24±0.36 a	0	0.01±0.02 a	0.05±0.06 a
Hyperiodrilus africanus	0	0	0	0	0	0.08±0.16 a	0	0	0

SA: Wooded Savannah, SH: Grassy Savannah, F: Forest

4 Discussion

4.1 Variability of identified species according to the position of the clitellum

Species with a clitellum near the anterior end of the body, notably *Dichogaster agilis, Dichogaster saliens*, and *Hyperiodrilus africanus*, lived in surface environments or in the upper horizons of the soil. Furthermore, this position was generally associated with worms of modest size. They were frequently classified among the epigeal or endogeal forms, characterized by significant activity in the decomposition of organic matter and the recycling of nutrients (Lavelle & Spain, 2001). Species with an intermediate clitellum (segments 17 to 20), notably *Dichogaster baeri*, *Scolecillus compositus*, and *Agastrodrilus sp*., exhibited intermediate characteristics, both morphologically and ecologically. Their clitellum position reflected a certain functional diversity, allowing them to occupy varied niches in the soil (Lavelle & Spain, 2001). They played a role both in the transformation of organic matter and in the improvement of soil structure. Species with a posterior clitellum, located further from the anterior region (segments 19 to 25), including *Stuhlmannia zielae, Stuhlmannia palustris,* and *Millsonia omodeoi*, exhibited a larger body size. They were generally associated with anecic worms, known for their major role in creating deep burrows, mixing soil horizons, and improving soil structure (Edwards & Bohlen, 1996). Their activity contributed significantly to soil aeration and water circulation. The position of the clitellum highlighted three distinct levels of dispersal within the studied species, reflecting significant morphological differences (Csuzdi, 2012).

4.2 Variability in earthworm species richness by facies and strata

Earthworm analysis revealed a vertical and horizontal organization linked to depth and habitat type. Species richness varied little between habitat types, with a slight dominance in forests due to high organic matter content and stable humidity (Blouin et al., 2013). The 0–10 cm stratum was the richest, dominated by *Dichogaster agilis, Dichogaster baeri, Stuhlmannia zielae*, and *Scolecillus compositus*, which thrived in the litter and humidity (Lavelle, 1978; Phillips et al., 2019). This richness was explained by the abundance of organic resources and favourable physical conditions.

In the 10–20 cm stratum, species richness decreased, especially in savannas, due to low organic matter content and more challenging conditions, unlike in forests (Blouin et al., 2013; Sutri et al., 2025). The 20–30 cm layer was dominated by endogeic species such as *Stuhlmannia zielae, Stuhlmannia palustris, Agastrodrilus sp*., and *Millsonia omodeoi* (Sutri et al., 2025; Phillips et al., 2019). *Scolecillus compositus* exhibited broad ecological tolerance, while Hyperiodrilus africanus was restricted to forest. Thus, distribution depended on the interactions between soil, depth, and vegetation (Lavelle, 1978; Tondoh, 1998; Blouin et al., 2013).

4.3 Earthworm density

The significant difference in density between the habitats could be explained by their structure. The denser forest retains moisture better, favoring the activity of earthworms such as *Stuhlmannia zielae*, unlike the drier savannas (Nacro, 1997; Lee, 1985). Soil temperature and moisture are key factors regulating their abundance and activity (Satchell, 1967; Hartenstein & Amico, 1983; Sims & Gerard, 1999), with populations responding rapidly to environmental changes (Pelosi, 2008). The higher density in stratum 1 (0-10 cm) can be explained by the strong presence of epigeic species such as *Dichogaster agilis* and *Dichogaster baeri*, characterized by a high reproduction rate but limited to the surface horizons (Bouché, 1959; Lee, 1959; Satchell, 1980). Endogenous species, notably *Stuhlmannia zielae*, occupy all strata thanks to their ability to migrate vertically (Bouché, 1959; Lee, 1959). The lack of difference between strata 2 and 3 could be explained by the absence of epigeic species in these horizons (Satchell, 1980). The difference observed in stratum 1 between facies would depend on soil texture. Indeed, forest soils would be more favorable than the sandy soils of savannas (Nacro, 1997). Finally, the dominance of *Stuhlmannia zielae* was explained by its adaptation to soil depths, allowing it to escape climatic constraints and predation (Lavelle, 1981).

4.4 Biomasses earthworms by facies and by stratum

Earthworm biomass decreases with depth. A maximum was observed in the 0-10 cm stratum, which was thought to be linked to the abundance of organic matter and favorable conditions (Lavelle, 1978; Blouin et al., 2013). The dominance of *Millsonia omodeoi* at the surface reflects these favorable conditions. Furthermore, *Dichogaster saliens* (10-20 cm stratum) and *Agastrodrilus sp*. (deep) illustrate ecological specialization (Bouché, 1959; Lee, 1985). The decrease in biomass at depth is explained by resource scarcity, compaction, and less favorable water conditions (Phillips et al., 2019). In savannas, these constraints were exacerbated by drought, unlike in the more stable forest (Blouin et al., 2013). The ANOVA ($p < 0.05$) confirms the effect of facies and stratum, and Tukey's test distinguishes the surface stratum from the deeper strata. Thus, biomass reflects the interaction between resources, edaphic conditions, and ecological strategies (Lavelle, 1978; Tondoh, 1998).

5 Conclusion

This study highlighted a marked spatio-vertical structuring of earthworm communities in Lamto, strongly influenced by soil depth and facies type. Species richness and biomass were highest in the surface layer (0–10 cm), where ecological conditions (organic matter, moisture, porosity) were most favorable. The progressive decrease with depth reflected increasing edaphic constraints and species specialization. The significant differences observed between savannas and forest confirmed the determining role of vegetation cover and microclimate. Finally, the species distribution reflected adapted ecological strategies, underscoring the importance of earthworms as bioindicators of the functioning and quality of tropical soils. Looking ahead, this study guided the selection of appropriate categories and species of earthworms for vermicomposting, particularly epigeic worms. Furthermore, for future earthworm farming, density and biomass should be taken into account as key parameters for optimizing production.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest to declare.

Authors contribution

Study design and execution: VH; data collection: VH and MNS; results analysis and interpretation: VH; manuscript writing: VH. All authors reviewed and approved the final version of the manuscript. Supervision : ST

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