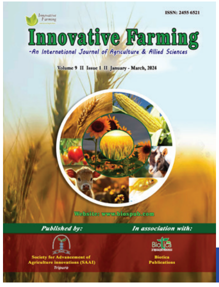

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Research Article

Ecological Assessment of Earthworm Communities in *Hevea brasiliensis* Plantations of Varying Age Groups in West Tripura, India

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Abstract

An ecological assessment was carried out in West Tripura, India to investigate the earthworm communities in *Hevea* plantations of distinct ages (3, 10, 14, 20 and 25 years) every month from June 2006 to May 2007. A total of twelve distinct species of earthworms from five families were found in the study area. The family Octochaetidae was represented by six species, including *Eutyphoeus assamensis*, *E. comillahnus*, *Lennogaster chittagongensis*, *L. yeicus*, *Octochaetona beatrix* and *Dichogaster affinis*. Other families included Megascolecidae (*Metaphire houlleti* and *Kanchuria* sp. 1), Moniligastridae (*Drawida nepalensis* and *D. papillifer papillifer*), Glossoscolecidae (*Pontoscolex corethrurus*) and Ocnerodrilidae (*Gordiodrilus elegans*).

The findings showed a favourable relationship between the plantation age and both the density and biomass of earthworm communities. Its dominance was evident as *Pontoscolex corethrurus* accounted for more than 60% of the total biomass of earthworms and 70% of the community density in all plantations. Exotic species such as *Metaphire houlleti* and *Pontoscolex corethrurus* exhibited uniform distribution across plantations of all age groups. Younger plantations (3 and 10 years) exhibited lower earthworm biomass, likely due to the high concentrations of polyphenols, flavonoids and lignin in the leaf litter, which negatively impacted earthworm activity. These compounds declined as the crops grew, which resulted in a notable rise in earthworm biomass. The overall findings of the study showed that the age of the plantations plays a significant role in evaluating the density, biomass and species dominance of earthworms, with older plantations sustaining more robust and diversified earthworm ecosystems. These results have significant ramifications for managing biodiversity and soil health in rubber plantation ecosystems.

Keywords: Biomass, Density, Earthworm, Hevea brasiliensis, Leaf Litter, Rubber

Introduction

Earthworms are widely recognized as essential for maintaining the healthy soil and ecosystem functions, particularly in farming systems. Their eating patterns and burrowing practices aid in the development of soil structure, nutrient cycling and the soil's assimilation of organic materials (Lowe *et al.*, 2014; Kahl and Johnson-Maynard, 2021). Understanding the ecological evaluation of earthworm communities in the context of *Hevea brasiliensis* (rubber) plantations might offer important insights into the resilience and sustainability of these agro-ecosystems.

The mid-19th century saw the beginning of a long and rich history for the study of earthworm variety in India. Understanding the ecological functions and taxonomic classification of earthworms in the subcontinent was made possible by early exploratory endeavours. One of the earliest notable contributions was made by Templeton (1844), who first described *Megascolex coeruleus* in Sri Lanka, marking

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the beginning of systematic earthworm studies in South Asia. Perrier (1872) extended these efforts to mainland India, and the path has been followed by seminal work from researchers like Beddard (1902), Michaelsen (1910), Stephenson (1930), Gates (1972), Kale and Krishnamoorthy (1978), Senapati and Dash (1983), Jamieson (1988), Julka (1988), Ismail (1997), Kale (1998), Paliwal and Julka (2005), Chaudhuri and Bhattacharjee (2005), Chaudhuri *et al.* (2008a,b), Sinha (2011) and Chaudhuri and Dey (2013). Their collective efforts significantly advanced the taxonomy and ecology of earthworms in India, revealing a diverse group of species uniquely adapted to the region's varied ecosystems. As per the findings of Julka and Paliwal (2005), native species comprise over 89% of the earthworm diversity in the nation, highlighting the abundance of India's soil biota.

Due to their significant impact on the decomposition of organic matter, nutrient cycling and soil structure, earthworms are frequently referred to be "ecosystem engineers", since they are essential parts of soil ecosystems. However, changes in land use can have a noteworthy impact on the demographic dynamics and composition of earthworm populations, as they are not static (Blanchart and Julka, 1997; Behera *et al.*, 1999; Bhaduria *et al.*, 2000). In particular, the conversion of natural forests into agricultural or plantation lands leads to shifts in earthworm populations, both in terms of species composition and functional roles. Plant species' direct and indirect effects on the soil and litter biota are responsible for these changes. While changes in canopy shading, soil protection and water and nutrient uptake by plant roots are examples of indirect effects; direct effects include variations in the quality and quantity of organic matter inputs above and below ground (Neher, 1999).

Surprisingly, plantation monoculture or polyculture does not seem to have as much of an impact on earthworm biomass as the identity of individual tree species (Sarlo, 2006). For instance, Gonzalez *et al.* (1996) and Tian *et al.* (2000) have shown that by adjusting the physicochemical characteristics of the soil, like pH, moisture, temperature and organic matter content, tree plantings can change the population of earthworms. In tropical ecosystems, where native plantations are dominant, earthworm communities often thrive, favoring the establishment of indigenous species (Zou and Gonzalez, 2001). These plantations not only sustain earthworm populations but also promote their ecological functions, including decomposition of organic matter and soil nutrient cycling.

The compositions of plant litter, particularly its chemical constituents, *viz.*, nitrogen, lignin and phenolic compounds, *etc*. are the fundamental determinants influencing the earthworm abundance. These compounds influence the palatability of litter for earthworms and the rate at which it decomposes (Edwards and Bohlen, 1996; Tian *et al.*, 2000; Sarlo, 2006). The size and composition of earthworm populations strongly affected by the availability and quality of food resources, as well as their reproductive success, growth rates and distribution (Chaudhuri *et al.*, 2003; Chaudhuri and Debnath, 2020). Although these dynamics have been extensively studied in temperate locations (Lee, 1985; Edwards and Bohlen, 1996; Hendrix and Bohlen, 2002), tropical ecosystems offer special circumstances that call for more research. Scholars in India have studied earthworm communities in a variety of habitats, such as tropical rainforests (Fragoso and Lavelle, 1987; 1992; Atkin and Proctor, 1988; Lavelle and Pashanasi, 1989), savannas (Lavelle, 1978; 1979; Martin *et al.*, 1990; Blanchart *et al.*, 1989), pastures (Dash and Patra, 1977; 1979; Lavelle, 1981; Chaudhuri and Bhattacharjee, 2005), plantation crops (Chaudhuri *et al.*, 2008a,b; Chaudhuri and Dey, 2013) and agro-ecosystems (Feijoo *et al.*, 2011) and farming ecosystems (Sathianarayanan and Khan, 2006).

Based on their dietary habits and preferred habitats, earthworms are designated into three main ecological groups: endogeic, anecic and epigeic species (Bouche, 1971; 1977). Typically found in surface litter layers, epigeic species like *Perionyx excavatus* and *Eisenia fetida* play a crucial role in the decomposition of organic matter. These species contribute to nutrient cycling by accelerating litter breakdown and facilitating microbial decomposition processes (Lavelle, 1988; Dash, 2012). *Anecic* species, such as *Lumbricus terrestris* and *Drawida grandis*, construct deep vertical burrows, playing a pivotal role in soil aeration and the redistribution of organic matter between the surface and deeper soil layers (Lavelle, 1988). *Endogeic* species, including *Pontoscolex corethrurus*, dwell within the mineral soil, where they ingest soil mixed with organic matter, thus enhancing soil structure and nutrient dynamics (Barois and Lavelle, 1986). These ecological divisions show how species have evolved to adapt to different soil and litter conditions. Some species even occupy intermediary ecological niches in order to maximise their use of resources.

The Forest Department strategically introduced *Hevea brasiliensis* (rubber) plants in 1963 in Tripura, India, with the goal of rehabilitating the local inhabitants and lessening the negative environmental effects of slash-and-burn agriculture. Despite being monocultural in nature, rubber plantations offer a special habitat for earthworms and other soil biota. Rubber plantations support shade-tolerant flora and fauna; however, their biodiversity is lower than that of natural forests. Research is still being done to identify the long-term ecological effects of rubber plantations on soil fauna, including earthworms. A salient feature of rubber plantations is the gradual breakdown of rubber tree leaf litter, which builds up on the forest floor for a significant portion of the year. This persistent layer of litter alters the microenvironment of the soil, potentially influencing the abundance, diversity and functional roles of earthworm communities.

Numerous investigations have looked at the populations of earthworms in various aged *Hevea brasiliensis* farms. According to Chaudhuri and Dey (2013), species richness and diversity tended to decline with plantation age, but older rubber plantations have demonstrated higher earthworm density and biomass. The study suggests that the ecological makeup and dynamics of earthworm communities change as rubber plantations get older. Comparable findings were documented by Cheng *et al.* (2007), who noted that despite the rubber plantations' high potential for sequestering carbon-dioxide; they saw a decrease in soil fertility and changes in soil physicochemical qualities during a 30-year period.

Evaluating the ecological effect and long-term viability of rubber plantations requires an understanding of the relationships between earthworm communities and plantation age. Plantations may become less able to sustain a variety of healthy earthworm populations as they get older, which could have an impact on the soil health and ecosystem mechanisms, including the nutrient cycling and the organic matter decomposition. Thus, the current study intends to examine the diversity of earthworms and the structure of communities among diverse age groups of *Hevea brasiliensis* plantations in West Tripura, India. The study aims to clarify how plantation age affects earthworm abundance, variety and ecological roles in a monocultural rubber agro-ecosystem by looking at earthworm populations in these plantations.

Materials and Methods

Study Site

Five rubber (*Hevea brasiliensis*) plantations of different ages, *viz.*, 3, 10, 14, 20 and 25 years, as well as an adjacent vacant plot that served as a control were used in the study. The locations of all the sites were in the Mohanpur Block of West Tripura, Northeast India, in the Taranagar area (geographical coordinates: 23°16´-24°14´ N and 91°09´-91°47´ E). With an average yearly temperature of 25 °C and 1500-2000 mm of precipitation, the region has a tropical humid climate. Four distinct seasons, *viz.*, summer (April to June), monsoon (July to October), winter (November to February) and spring (March) of 2006 and 2007 define the research region.

The study locations were set on slightly undulating terrain and the soil in the region is primarily acidic. Rubber plantations were done in rows with a spacing of 4.5-5.0 m between each tree. The juvenile plantation (3 years) had sparse canopy coverage and the ground cover was dominated by leguminous crops like *Pueraria phaseoloides* and grasses, with minimal accumulation of *Hevea* leaf litter. In contrast, the mature plantations (14, 20 and 25 years) and young plantations (10 years) featured well-developed canopy cover with accumulated Hevea leaf litter on the forest floor. The adjacent unutilized plot, serving as a control, was an open field with natural vegetation dominated by *Chrysopogon aciculatus* and grasses. This uncultivated plot was maintained to compare the natural, unmanaged ecosystem with the rubber plantation environments.

A detailed comparison of the soil's physico-chemical properties across the different plantation sites and the control plot is presented in table 1.

Earthworm Population Sampling

To assess the earthworm community structure, five widely spaced sampling plots (10 m × 10 m) were established within each of the five rubber plantations and the control plot. Sampling was performed monthly to capture seasonal variations in earthworm populations. Within each plot, five composite samples were collected, comprising 25 sub-samples (each measuring 25 cm × 25 cm × 30 cm in depth) selected randomly throughout the plot.

Table 1: A comparison between some physico-chemical properties of the soils of the rubber (Hevea) plantations of different age groups and adjoining unutilized land in Taranagar, West Tripura

Edaphic Parameters	Habitats of Hevea plantation					
	Unutilized land	3 years old	10 years old	14 years old	20 yr old	25 years old
Soil texture	Sandy	Loamy; sand	Loamy; sand	Sandy	Sandy	Loamy; sand
Temperature (°C); (n=100)	26.17±0.56	27.14±0.55	25.08±0.45	25.05±0.53	24.87±0.52	24.81±0.53
Moisture (%); (n=100)	10.87±0.25	15.80±0.56	15.95±0.56	16.20±0.31	16.87±0.48	17.41±0.69
pH; (n=20)	4.89±0.08	4.88±0.08	4.58±0.04	4.74±0.08	4.78±0.05	4.59±0.01
Organic matter (g %); (n=10)	1.82±0.04	1.75±0.08	2.06±0.13	1.28±0.14	2.05±0.16	1.80±0.04
Potassium (mg/ 100 g); (n=10)	1.54±0.11	1.48±0.26	1.77±0.36	0.78±0.08	0.55±0.18	1.49±0.44
Calcium (mg/ 100 g); (n=10)	151.21±0.51	161.18±0.27	163.25±0.16	368.96±0.44	354.42±0.11	105.16±0.86
Phosphate (mg/ 100 g); (n=10)	4.39±0.99	5.62±1.36	4.56±0.60	0.81±0.05	0.89±0.07	4.96±1.03
Kjeldahl Nitrogen* (%); (n=10)	0.012±0.00	0.009±0.00	0.007±0.00	0.011±0.00	0.016±0.00	0.008±0.00

*Kjeldahl Nitrogen = Organic + Ammonia forms of nitrogen

The earthworms were recovered from the sub-samples by manual-sorting and ordinary digging, which is a tried-and-true approach for gathering fauna that lives in the soil. In the field, the removed specimens were weighed and counted right away. For accurate taxonomic identification, a representative subset of ten to fifteen samples from each recognised species were stored in 4% formalin and forwarded to the Zoological Survey of India in Solan, Himachal Pradesh.

The earthworm population was quantified in terms of: (i) Biomass (fresh weight, g m^{-2}) and (ii) Density (number of individuals m^{-2}). The total biomass and density for each site were calculated to compare the earthworm population across the different plantations and the control plot. A comparison of plantation characteristics and earthworm population parameters is summarized in table 2.

Table 2: A comparison between some characteristic features of rubber (Hevea) plantations of different age groups and adjoining unutilized land in Taranagar, West Tripura

Plantation Characteristics	Unutilized land	Hevea plantation				
		3 years old	10 years old	14 years old	20 yr old	25 years old
Canopy cover	Absent	Absent	Present	Present	Present	Present
Ground cover	Grass	Leguminous plant and grass	Hevea leaf litter	Hevea leaf litter	Hevea leaf litter	Hevea leaf litter
Amount of Hevea leaf litter (kg m^{-2}); (n= 40)	Absent	0.002-0.006	0.2-0.7	0.7-1.2	0.6-1.1	0.8-1.5
Girth of tree at a height of 120 cm (cm); (n= 40)	-	6.0-17.0	61.0-71.4	72.0-94.5	73.0 -102.0	90.0-114.3
Earthworm casts (g m^{-2}); (n= 40)	4	2	67	ND	75	849
Latex collection	-	-	++++	++++	+	+
Fertilizer application	-	++	++++	+++	+	+
Human interference	+	++	++++	+++	++	+

[ND = Not determined, + present, ++ moderate, +++ high, ++++ highest]

Soil Analysis

A thorough soil investigation was carried out at each sampling location in order to establish a linkage between earthworm variety and abundance and the physico-chemical characteristics of the soil. The following measurements of soil pH, moisture content and temperature were made in the field and in the lab.

• *Soil Temperature*: Measured with a soil thermometer at a depth of 0-15 cm.

• *Soil Moisture*: Determined at a depth of 0-15 cm using gravimetric methods. Using this technique, fresh soil samples were weighed, dried at 105 °C until their weight remained constant and the moisture content was estimated as a percentage of the dry weight.

• *Soil pH*: Estimated with a soil-to-water suspension ratio of 1:2.5. This required adding distilled water to the soil, letting it settle and using a digital pH meter that was calibrated to measure the pH.

To give a thorough picture of the soil's nutritional profile, other soil parameters were examined in the lab:

• *Soil Organic Carbon*: Measured using the Rapid Titration Method of Walkley and Black (1934). Using potassium dichromate and sulphuric acid to oxidise soil organic materials, then titrating the mixture to determine the carbon content.

• *Nitrogen Content*: Measured using the widely-used Micro-Kjeldahl method, which involves digesting the sample with strong sulphuric acid and quantifying the ammonium nitrogen that results.

• *Soil Texture*: Evaluated with a soil hydrometer to ascertain the ratios of silt, sand and clay, which characterise the class of soil texture.

• *Potassium and Calcium*: Measured using flame photometry, which examined soil extracts to determine the amounts of calcium and potassium ions by looking for light emission at particular wavelengths.

• *Phosphorus Content*: using Troug's approach, which entails removing soil sample's accessible phosphorus and detecting it at particular wavelengths with a UV-VIS spectrophotometer.

These physico-chemical parameters were crucial for evaluating the influence of soil properties on earthworm populations across different plantation ages and the control plot.

Leaf Litter Chemical Analysis

A chemical analysis of the Hevea leaf litter was done in order to comprehend how the composition of the litter affects earthworm abundance and activity. From every plantation, leaves (blade and petiole) were gathered, oven-dried at 60 °C dried in oven and then milled into a fine powder. Standard analytical techniques were used to measure the following chemical parameters.

• *Sugar Content*: Determined using the anthrone method, which involves reacting anthrone reagent in an acidic solution to quantify sugars colorimetrically.

• *Lignin Content*: Measured using the acid detergent fibre (ADF) method, which separates and quantifies lignin by digesting the plant material with sulphuric acid.

• *Polyphenol Content*: Analyzed using the Folin-Ciocalteu method, which yields a colour shift that a spectrophotometer can detect and quantifies the total phenolic content by reacting with Folin-Ciocalteu reagent.

• *Flavonoid Content*: Assessed with a common spectrophotometric technique based on the creation of a compound between flavonoids and aluminium chloride that absorbs light at a certain wavelength.

To evaluate their possible effects on earthworm biomass, activity and overall population dynamics across plantations of different ages, these chemical characteristics of the *Hevea* leaf litter were assessed.

Data Analysis

All data collected from the earthworm sampling, soil analysis and leaf litter chemical composition were subjected to statistical analysis to uncover relevant distinctions between the various plantation age groups and the control plot. The statistical methods included:

• *Descriptive Statistics*: Used to summarize the key earthworm population parameters (biomass, density) and soil properties across the sites.

• *Analysis of Variance (ANOVA)*: Conducted to establish whether the chemical composition of leaf litter, soil characteristics and earthworm populations varied statistically significant between the control plot and the various plantation ages. Tukey's HSD tests were utilised to pinpoint certain group differences.

• *Correlation and Regression Analysis*: Investigated the links between earthworm populations and the characteristics of the soil and leaf litter, identifying the variables that have the greatest impact on the diversity and abundance of earthworms.

Using the proper software programs (*e.g.*, SPSS, R), all statistical analyses were carried out and results were deemed considerable at $p<0.05$.

Results and Discussion

Earthworm Species Diversity and Abundance

According to the study, most earthworms are inhabited in the top 0-15 cm of the soil, which is abundant in organic matter and creates an environment that is ideal for nutrient uptake and habitat stability in rubber plantations. Twelve earthworm species, representing nine genera and five families in the class Oligochaeta, were found in all, spanning the five plantations and the control plot (Figure 1). Among the species recorded, six were classified under the family Octochaetidae, including *Dichogaster affinis* (Michaelsen), *Eutyphoeus comillahnus* (Michaelsen), *E. assamensis* (Stephenson), *Lennogaster chittagongensis* (Stephenson), *L. yeicus* (Stephenson) and *Octochaetona beatrix* (Beddard). Two species each belonged to Moniligastridae (*Drawida nepalensis* Michaelsen and *D. papillifer papillifer* Stephenson) and Megascolecidae (*Metaphire houlleti* (Perrier) and *Kanchuria* sp. 1). Additionally, one species each from Ocnerodrilidae (*Gordiodrilus elegans* Beddard) and Glossoscolecidae (*Pontoscolex corethrurus* Müller) was identified.

Of the species collected, *Dichogaster affinis*, *Gordiodrilus elegans*, *Metaphire houlleti* and *Pontoscolex corethrurus* are considered exotic species, having been introduced from outside the region. In contrast, *Kanchuria* sp. 1, *Eutyphoeus comillahnus* and *Eutyphoeus assamensis* are endemic to the region, contributing to the distinctiveness of Tripura's earthworm fauna. The remaining species, such as *Lennogaster chittagongensis*, *Lennogaster yeicus*, *Octochaetona beatrix*, *Drawida nepalensis* and *Drawida papillifer papillifer*, are classified as native peregrine species. These findings not only enrich the existing knowledge of earthworm diversity in Northeastern India, but also include several species recorded for the first time from Tripura, notably *Dichogaster affinis*, *Octochaetona beatrix*, *Kanchuria* sp. 1 and *Lennogaster yeicus*.

Ecological Categories and Distribution Patterns

Based on their dietary patterns and preferred habitats, the species found in this study were broadly characterized into three groups: epigeic, anecic and endogeic. These groups displayed a variety of ecological roles (Table 3). Several important ecological characteristics, such as soil temperature, moisture content, pH and organic matter content, showed a substantial correlation with the spread of these species (Table 4). The mean earthworm density across the plantations was 56.86 individuals m^{-2} and the biomass was 22.92 g m^{-2}. *Dichogaster affinis* showed the lowest values, while *Pontoscolex corethrurus* showed the highest density and biomass, showing its adaption to the plantation environment.

It was shown that soil moisture significantly affected earthworm populations and there was a positive correlation between moisture levels and density ($p=0.01$) as well as biomass ($p=0.02$). Earthworm biomass ($p=0.00$) and density ($p=0.00$) were positively linked with soil temperature in the 19 °C to 29 °C range, suggesting that warmer temperatures encourage earthworm activity. On the other hand, figure 2 shows a negative link between soil pH and biomass as well as density, indicating that the acidity of the soil may prevent earthworm proliferation in some regions. These results indicate that moist, warm and moderately acidic environments are optimal for earthworm growth in rubber plantations.

Comparison with Previous Studies

The results of this investigation align with earlier studies on the diversity of earthworms in Northeastern part of India. For instance, Haokip and Singh (2012) documented the

Family: Glossoscolecidae

Family: Megascolecidae

(a) *Pontoscolex corethrurus*

(b) *Kanchuria* sp.1

(c) *Metaphirehoulleti*

Family: Moniligastridae

(d) *Drawida nepalensis*

(e) *Drawida papillifer papillifer*

Family: Ocnerodrilidae

(f) *Gordiodrilus elegans*

Family: Octochaetidae

(g) *Dichogaster affinis*

(h) *Eutyphoeus assamensis*

(i) *Eutyphoeus comillahnus*

(j) *Lennogaster chittagongensis*

(k) *Lennogaster yeicus*

(l) *Octochaetona beatrix*

Figure 1: Twelve species of earthworms found in the rubber plantations of Mohanpur Block, West Tripura

presence of *Pontoscolex corethrurus*, *Metaphire houlleti* and *Lennogaster yeicus*, along with species of *Drawida* and *Eutyphoeus*, in the subtropical forest ecosystems of Imphal, Manipur. Similarly, Lalthanzara and Ramanujan (2012) reported *Metaphire houlleti* and species of *Drawida* in agroforestry systems in Mizoram. Several species detected in the present study, including *Pontoscolex corethrurus*, *Metaphire houlleti*, *Drawida nepalensis*, *Gordiodrilus elegans* and *Octochaetona beatrix*, have also been recorded in various habitats across West Bengal (Halder, 1999).

Table 3: Ecological categories, habitat, feeding and morphological characteristics of some earthworm species of Mohanpur Block, West Tripura

Family and Earthworm species	Ecological category	Distribution pattern	Feeding habit	Size (mm)	Pigmentation
Glossoscolecidae					
Pontoscolex corethrurus	Topsoil endogeic	Exotic peregrine	Geophagus	72-100 × 4.0-5.0	Lightly pigmented
Megascolecidae					
Kanchuria sp.1	Subsoil endogeic	Endemic	Geophagus	200-257 × 3.5-5.5	Lightly pigmented
Metaphire houlleti	Epianecic	Exotic peregrine	Phytogeophagus	100-160 × 3.0-6.0	Deeply pigmented dorsally
Moniligastridae					
Drawida nepalensis	Topsoil endogeic	Native peregrine	Geophagus	60-80 × 4.0-5.0	Lightly pigmented
Drawida papillifer papillifer	Epianecic	Native peregrine	Phytogeophagus	45-100 × 3.0-4.0	Deeply pigmented
Ocnerodrilidae					
Gordiodrilus elegans	Topsoil endogeic	Exotic	Geophagus	35-50 × 1.5-2.0	Very lightly pigmented
Octochaetidae					
Dichogaster affinis	Epigeic	Exotic peregrine	Phytophagus	35-42 × 1.0-2.0	Moderately pigmented
Eutyphoeus assamensis	Subsoil endogeic	Endemic	Geophagus	100-198 × 5.0-6.0	Lightly pigmented
Eutyphoeus comillahnus	Subsoil endogeic	Endemic	Geophagus	70-135 × 2.0-4.0	Lightly pigmented
Lennogaster chittagongensis	Topsoil endogeic	Native peregrine	Phytogeophagus	40-53 × 1.5-2.5	Moderately pigmented
Lennogaster yeicus	Topsoil endogeic	Native peregrine	Phytogeophagus	30-60 × 1.5-2.5	Moderately pigmented
Octochaetona beatrix	Subsoil endogeic	Native peregrine	Geophagus	60-120 × 4.0-5.0	Lightly pigmented

Interestingly, species such as *Eutyphoeus comillahnus* and *Kanchuria* sp. 1 were unique to Tripura, underscoring the distinct biogeographical character of the region. The observed similarities in earthworm fauna between Tripura, other Northeastern states and neighbouring Bangladesh can be attributed to passive dispersal and migration facilitated by land connections in this area.

Influence of Plantation Age on Earthworm Communities

The influence of plantation characteristics, particularly age, on earthworm communities was evident in this study. According to the earlier research by Chaudhuri and Dey (2013), earthworm biomass and density tend to rise with plantation age while species diversity tends to decrease. These trends were also seen in this study, where older plantations (20 and 25 years) showed higher earthworm biomass and density than younger plantations. This increase in population parameters with plantation age likely reflects the progressive development in soil conditions, like organic matter content and microclimatic stability, as the plantations mature.

Despite the substantial input of leaf litter within the rubber plantations, the non-existence of anecic earthworms and the relative scarcity of epigeic species suggest that the high polyphenol content of *Hevea* leaf litter may reduce its palatability (Chaudhuri *et al.*, 2003). Chemical analysis of the leaf litter revealed variations in the concentration of polyphenols, flavonoids, sugars and lignin across plantations of different ages. Earthworm biomass was negatively correlated with polyphenol and lignin content (Figure 3), highlighting the influence of litter quality on earthworm populations. The 14-year-old plantation exhibited the highest biomass, which coincided with the lowest concentrations of polyphenols and lignin and the highest sugar content in the leaf litter, suggesting that improved food quality supports higher earthworm activity.

Comparison with Unutilized Land

It was discovered that, in comparison to the rubber plantations, the nearby vacant ground, which functioned as the control plot, supported noticeably lower earthworm density, biomass and species diversity. The improved

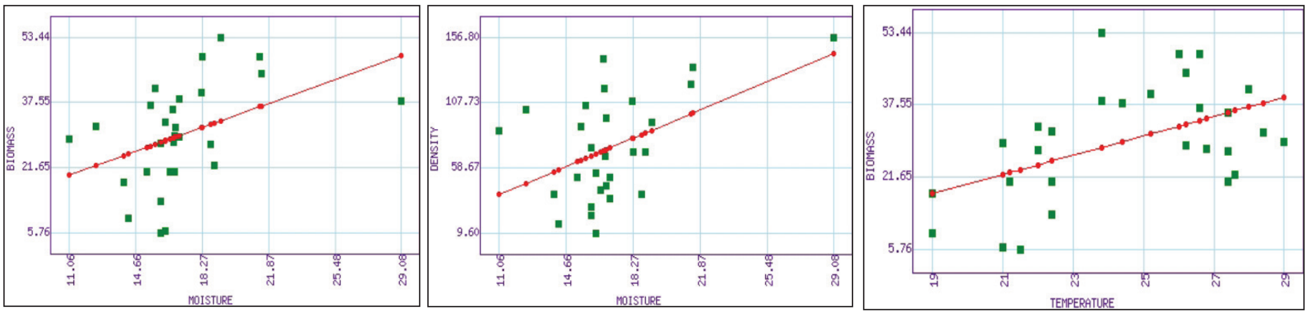
Table 4: Occurrence of earthworm species of rubber plantations of Mohanpur Block under different ecological conditions

Family and Earthworm species	Soil Temperature(c°)	Soil Moisture (g %)	Soil pH	Soil Organic Matter (g %)
Glossoscolecidae				
Pontoscolex corethrurus	25.85±0.19 (19.0-32.2)	22.97±0.74 (10.00-29.08)	4.68±0.06 (4.54-4.87)	1.40±0.12 (1.72-2.42)
Megascolecidae				
Kanchuria sp.1	26.01±0.22 (23.0-27.0)	18.62±0.66 (16.50-20.00)	4.56±0.07 (4.60-4.71)	1.50±0.07 (1.43-1.59)
Metaphire houlleti	24.06±0.05 (21.0-28.0)	20.00±0.89 (13.70-20.35)	4.93±0.14 (4.43-5.21)	1.66±0.17 (1.64-1.92)
Moniligastridae				
Drawida nepalensis	25.84±0.28 (21.0-30.2)	23.08±0.36 (10.00-29.08)	4.75±0.13 (4.43-5.21)	1.53±0.26 (1.64-2.42)
Drawida papillifer papillifer	25.24±0.18 (22.0-32.2)	24.18±0.74 (10.08-29.08)	4.65±0.03 (4.54-4.76)	1.55±0.07 (1.52-1.92)
Ocnerodrilidae				
Gordiodrilus elegans	24.16±0.12 (20.0-26.8)	16.72±0.57 (14.56-17.98)	4.42±0.01 (4.43-4.66)	1.85±0.08 (1.64-2.01)
Octochaetidae				
Dichogaster affinis	23.40±0.04 (21.0-23.0)	21.40±0.20 (17.00-21.00)	4.63±0.04 (4.54-4.76)	1.85±0.02 (1.80-1.92)
Eutyphoeus assamensis	26.09±0.50 (26.2-28.8)	20.96±0.71 (18.21-21.62)	4.21±0.20 (4.06-5.03)	1.50±0.07 (1.43-1.80)
Eutyphoeus comillahnus	24.20±0.86 (21.0-26.0)	17.77±0.22 (17.00-18.21)	4.59±0.01 (4.58-4.60)	1.70±0.15 (1.72-1.84)
Lennogaster chittagongensis	25.08±0.32 (24.0-28.8)	16.62±0.63 (12.04-18.15)	4.81±0.02 (4.77-4.87)	1.60±0.02 (1.52-1.64)
Lennogaster yeicus	23.56±0.54 (21.5-24.6)	16.88±0.23 (12.04-16.25)	4.78±0.03 (4.71-4.81)	1.59±0.02 (1.52-1.64)
Octochaetona beatrix	24.78±0.68 (20.0-30.2)	15.58±0.51 (10.08-19.21)	4.75±0.14 (4.76-5.21)	1.64±1.23 (1.52-1.88)
Mean ± S.E	24.86±0.28	19.56±0.54	4.65±0.06	1.61±0.04

habitat quality for earthworms was probably caused by the build-up of organic matter from leaf litter as well as more suitable moisture and temperature conditions in the rubber plantations. As the rubber plantations became older, the soil's stabilising environment and rising organic inputs offered a friendly environment for a variety of earthworm groups.

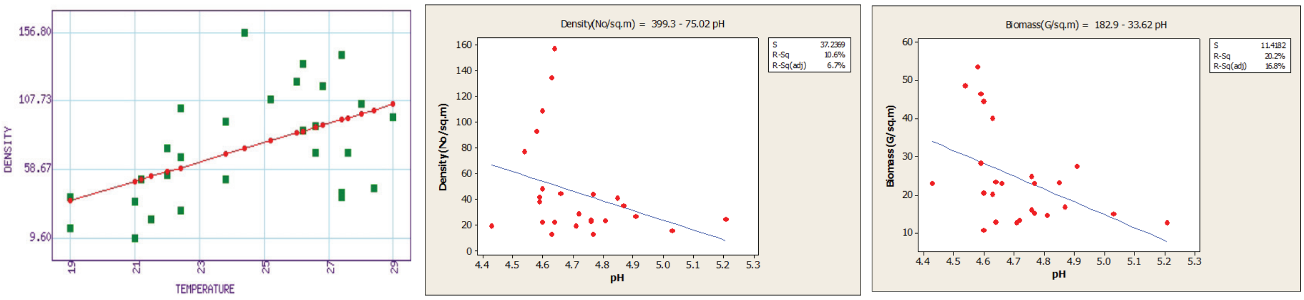
Ecological Implications

The study's findings highlight the significance of soil characteristics, plantation age and the makeup of leaf litter in forming earthworm populations in rubber plantations. This study showed that rubber plantations may sustain a diversified and healthy earthworm population, despite the



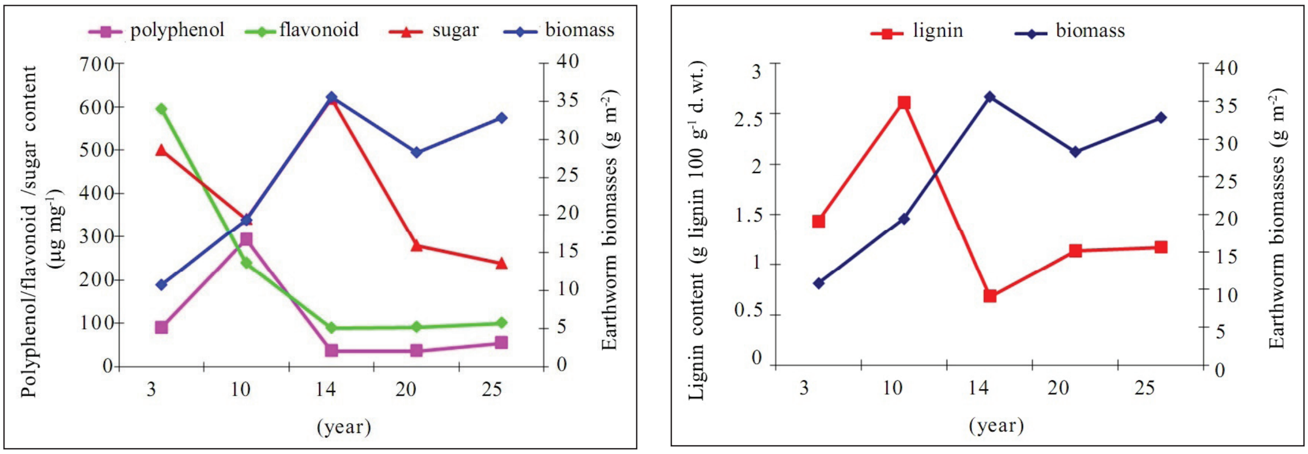
(a) moisture vs. biomass (b) moisture vs. density (c) temperature vs. biomass

Figure 2: Continue...



(d) temperature vs. density (e) pH vs. biomass (f) pH vs. density

Figure 2: Relationship between density and biomass of earthworms with soil moisture, soil temperature and soil pH against biomass and density in the Hevea plantation of Mohanpur Block, West Tripura



(a) Changes in polyphenol, flavonoid and sugar contents (b) Changes in lignin content

Figure 3: Variations in the earthworm biomasses with changes in different contents in the leaves of different age groups of *Hevea* Plantations

fact that monoculture plantations are generally linked to lesser biodiversity than natural forests. Earthworms are fundamental to the health of soil and the functioning of ecosystems because they cycle nutrients, break down organic matter and form soil structures. As such, their presence and abundance in rubber plantations have a significant influence on the long-term viability of these agro-ecosystems.

The results also show that rubber plantations have the potential to enhance biodiversity and soil quality over time, especially in areas where land degradation has been a major concern. Moreover, the observed correlation between plantation age and earthworm populations implies that older plantations would be more important for supporting soil health and biodiversity preservation.

Conclusion

The presence of native earthworm species in large numbers in Tripura's rubber plantations indicates that native species in Northeast India are more resilient to human disturbances. A variety of ecological factors, such as changes in canopy cover that affect sunlight penetration and variations in the amount and quality of leaf litter, may be responsible for this resilience. Additionally, the observed variations in earthworm abundance and community structure among plantations of varying ages have probably been influenced by soil properties, like moisture, temperature, organic matter concentration and human interventions.

The study emphasises how management techniques and plantation age shape earthworm biomass and variety, with older plantations offering more conducive environments for earthworm communities. These results underline the necessity of sustainable land management techniques that preserve ecological balance while highlighting the potential of rubber plantations to support native biodiversity. In order to further improve the ecological sustainability of rubber plantations in the area, future study should concentrate on comprehending the particular interactions between earthworms and plantation dynamics.

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