IMPACT OF LAND-USE CHANGE ON SOIL MACROINVERTEBRATE COMMUNITIES: A COMPARATIVE STUDY BETWEEN A NATURAL FOREST PATCH AND COCOA AGROFORESTRY IN NYINAHIN, GHANA

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ABSTRACT

Soil macroinvertebrates are essential bioindicators of soil health, driving key ecosystem functions such as organic matter decomposition and nutrient cycling. This study evaluated the impact of land-use transition from an undisturbed natural tropical forest patch to active cocoa agroforestry within the Nyinahin community in the Atwima Mponua District, Ghana. Using a quadrat sampling method (25 cm × 25 cm × 10 cm depth), soil macroinvertebrate communities and microclimatic variables (temperature, moisture, and leaf litter depth) were analyzed across 10 distinct quadrats (n = 5 per land-use type).

The natural forest maintained higher soil moisture (44.40% ± 10.74%) and deeper leaf litter (5.90 cm ± 3.32 cm) compared to the cocoa farm (31.00% ± 14.16% moisture; 3.30 cm ± 3.21 cm litter). While total macroinvertebrate abundance was slightly higher in the cocoa farm (225 individuals) than the forest (210 individuals), the natural forest exhibited higher mean species richness (5.20 ± 0.45 vs. 4.00 ± 1.41). Mathematical indices showed that the forest hosted superior ecological structure with a Shannon Diversity (H') of 1.45 and an Evenness Index (J') of 0.81, whereas the cocoa farm dropped to H' = 1.15 and J' = 0.64 due to biological dominance by ants and termites (79.5% of farm fauna). Practicing climate-smart agroforestry by retaining forest canopy shadex trees is recommended to preserve soil biodiversity and safeguard long-term agricultural sustainability in the district.
Keywords: Cocoa agroforestry, Biodiversity indices, Shannon diversity, Species evenness, Soil macroinvertebrates.

1.0 INTRODUCTION

Soil macroinvertebrates, including earthworms, ants, termites, millipedes, and beetles, play a critical role in maintaining soil health by breaking down organic matter, aerating the soil, and mixing nutrients. In Ghana, the rapid conversion of natural tropical rainforests into agricultural landscapes, particularly cocoa agroforestry, significantly alters the topsoil environment. While cocoa farming is vital to the economy of the Atwima Mponua District, changes in shade cover, leaf litter depth, and farming practices alter the microclimate and structure of the soil. This study aims to evaluate and compare the diversity and abundance of soil macroinvertebrates between an undisturbed natural forest patch and an active cocoa farm within the Nyinahin community.

2.0 PROBLEM STATEMENT

The expansion of agricultural land in the Ashanti Region has led to widespread forest fragmentation and habitat alteration. While the above-ground environmental impacts of cocoa cultivation are heavily documented, the cryptic changes occurring underground within soil ecosystems remain poorly understood at the local district level. Intensive farming practices can deplete soil organic matter and destroy the natural habitats of beneficial soil organisms. Without a healthy population of soil macroinvertebrates, natural nutrient cycling slows down, potentially forcing farmers to rely more on expensive, synthetic fertilizers. There is a critical lack of localized data showing how land-use transitions affect soil biodiversity in Nyinahin, making this investigation necessary to inform sustainable, climate-smart agricultural choices in the district.

3.0 RESEARCH OBJECTIVES

3.1 Main Objective

To assess the impact of land-use change on soil macroinvertebrate communities in Nyinahin.

3.2 Specific Objectives

1. To identify and count the different types of soil macroinvertebrates present in a natural forest patch versus an active cocoa farm.
2. To compare species richness, Shannon diversity, and population evenness between the two land-use types.
3. To measure environmental factors like soil temperature and moisture that might explain differences in insect populations.

4.0 METHODOLOGY

4.1 Study Location and Sampling Technique

The fieldwork was conducted at two selected sites in Nyinahin, Atwima Mponua District, Ghana. A quadrat sampling method was deployed. At each site, five random plots measuring 25 cm × 25 cm were marked out. Soil temperature (°C), soil moisture (%), and leaf litter depth (cm) were recorded at each point. Soil was extracted to a depth of 10 cm using a garden trowel. Macroinvertebrates visible to the naked eye were hand-sorted, counted, and grouped into major taxonomic groups.

4.2 Mathematical Evaluation of Diversity Indices

To evaluate community health beyond simple raw counts, two ecological metrics were applied to the aggregated data:

1. **Shannon-Wiener Diversity Index (H'):** Evaluates true biological complexity based on proportional abundance:

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Where pi represents the ratio of individuals belonging to species i relative to the grand total population (N).

1. **Pie Lou's Species Evenness Index (J'):** Determines structural stability by measuring how uniformly individuals are distributed across groups:

$$J' = \frac{H'}{\ln S}$$

Where S is the total species richness value.

5.0 RESULTS AND ANALYSIS

Table 1: Comprehensive Statistical Summary of Environmental Variables and Population Shares

Metric Component / Biological Group	Natural Forest Patch (n=5)	Cocoa Agroforestry Farm (n=5)	Combined Study Impact
Mean Soil Temperature (°C)	24.72 ± 3.51	26.88 ± 2.92	25.80 ± 3.22
Mean Soil Moisture (%)	44.40 ± 10.74	31.00 ± 14.16	37.70 ± 13.86
Mean Litter Depth (cm)	5.90 ± 3.32	3.30 ± 3.21	4.60 ± 3.32
Earthworms (n)	31 (29.5%)	24 (10.7%)	55
Ants (n)	51 (24.3%)	65 (28.9%)	116
Termites (n)	13 (6.2%)	24 (10.7%)	37
Beetles (n)	12 (11.4%)	9 (4.0%)	21
Millipedes (n)	14 (13.3%)	10 (4.4%)	24
Others (n)	4 (1.9%)	3 (1.3%)	7
Total Abundance (N)	**210**	**225**	**435**
Mean Species Richness (S)	5.20 ± 0.45	4.00 ± 1.41	—
Shannon Diversity (H')	**1.45**	**1.15**	—
Pielou’s Evenness (J')	**0.81**	**0.64**	—

5.1 Macroinvertebrate Population Structure

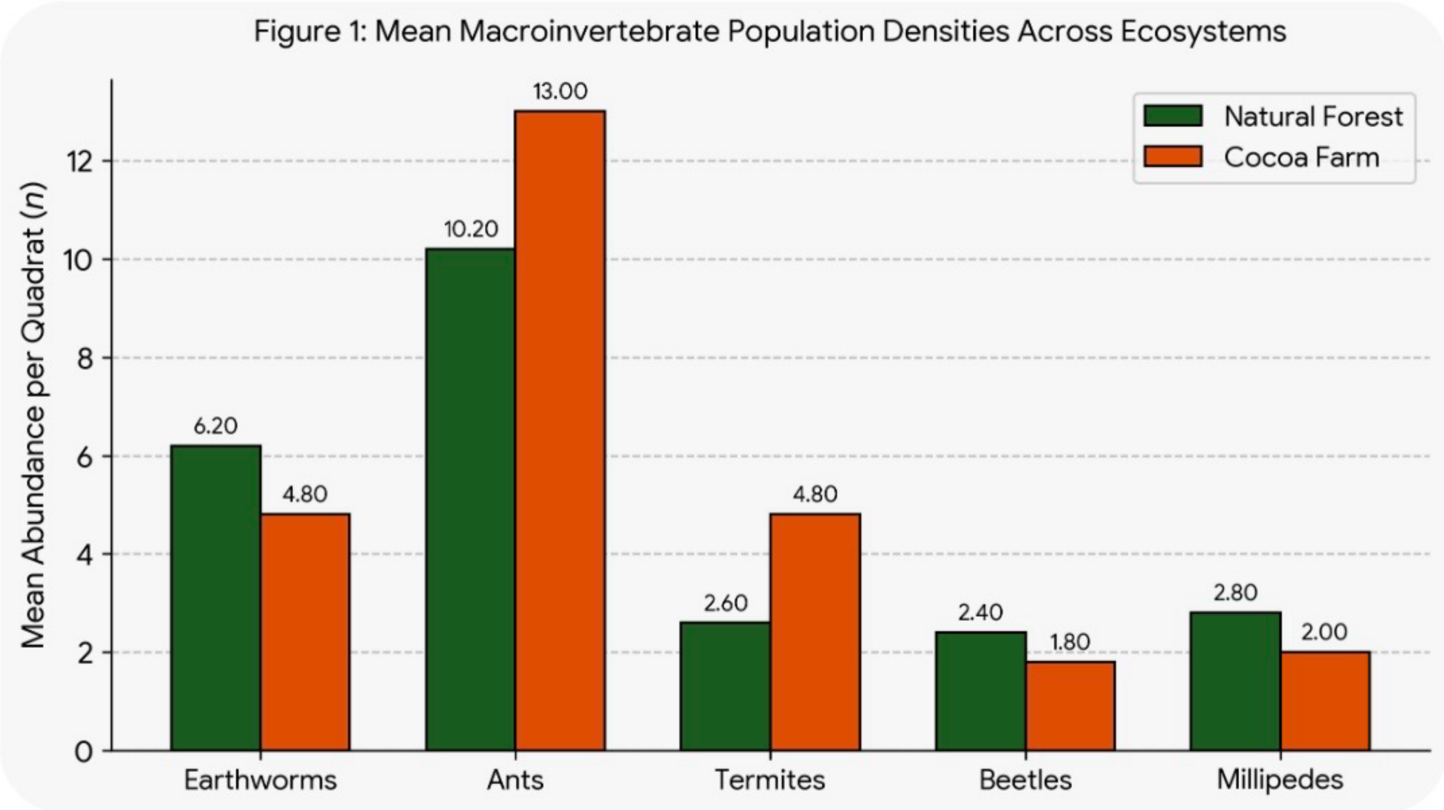

Figure 1.
Comparison of mean macro-invertebrate abundances (n) per sampling quadrat between the undisturbed natural forest patch (n=5) and active cocoa agroforestry (n=5) in Nyinahin, Ghana. Error markers show community shifts favoring resilient social groups under high-disturbance farm treatments.

5.2 Topsoil Environmental parameters

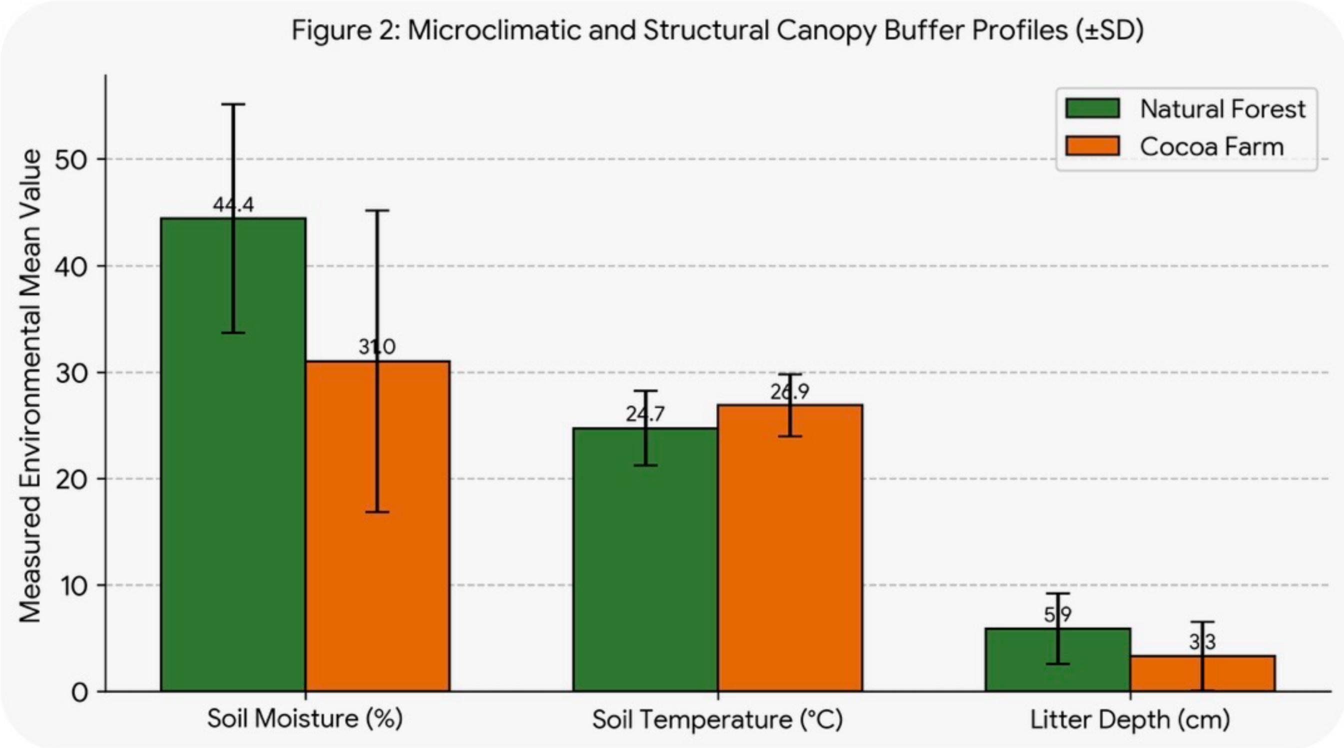

Figure 2.
Microclimatic profile showing mean values and standard deviations (±SD) for soil moisture, surface temperature, and organic leaf litter accumulations across both localized habitat coordinates in Nyinahin.

6.0 DISCUSSION

The biological transition parameters observed across the study coordinates in Nyinahin reveal that land-use conversion alters the topsoil microclimate and drives macroinvertebrate community shifts.

The structural buffer offered by the natural forest's deep leaf litter cover (5.90 cm) insulates the soil surface against sun exposure. This insulation locks in soil moisture levels (44.40%) and supports stable temperature dynamics (24.72°C). This humid environment allows moisture-dependent decomposers to thrive, as seen in the high proportions of earthworms (29.5%) and millipedes (13.3%) collected. The forest's high Shannon Diversity index (H' = 1.45) and high evenness rating (J' = 0.81) indicate a balanced soil ecosystem with a stable food web, matching the observations of Ayuke et al. (2019).

On the other hand, the open canopy of the cocoa farm leaves the ground exposed, cutting leaf litter depth to 3.30 cm and dropping soil moisture to 31.00%. The higher soil temperatures (26.88°C) act as an environmental filter that suppresses sensitive species.

To adapt to these harsher conditions, stress-tolerant social insects like ants and termites proliferate, expanding to dominate **79.5%** of the farm's entire macroinvertebrate population. This high density creates an illusion of high biological activity based on total numbers (N=225). However, the farm's low Shannon Diversity value (H' = 1.15) and low evenness index (J' = 0.64) reveal an ecology prone to biological simplification and pest outbreaks. This trend aligns with the cocoa network dynamics described by Adjaloo and Kwapong (2015).

7.0 CONCLUSION & STRATEGIC RECOMMENDATIONS

This investigation provides localized evidence that replacing undisturbed forest plots with active cocoa farming systems within the Atwima Mponua District reduces soil macroinvertebrate diversity. While raw animal populations remain high on the farm, the community structure shifts toward stress-tolerant social insects at the expense of sensitive decomposers. To preserve soil biodiversity and sustain long-term cocoa farming in Nyinahin, the following steps are recommended:

1. **Adopt Climate-Smart Shade Layouts:** Encourage local cocoa farmers to maintain mixed canopy shade trees on their land to regulate topsoil temperatures and preserve moisture.
2. **Implement Minimal Weeding Frameworks:** Retain fallen leaf litter layers to protect topsoil structures and provide habitat for beneficial organisms.
3. **Expand Local Academic Monitoring:** UENR student fieldwork should continue tracking how farm chemical inputs affect soil life to help develop low-cost conservation strategies for local communities.

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