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Journal of Sylva Indonesiana

Journal homepage: https://talenta.usu.ac.id/jsi

Comparative Study of Physiochemical Properties and Microbial Population in Forest and Shifting Cultivation Soil in Mizoram, India

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ARTICLE INFO

Article history:
Received December 18th, 2024
Revised February 7th, 2025
Accepted February 12th, 2025
Available online February 28th, 2025

E-ISSN: 2622-5093
P-ISSN: 2622-5158

How to cite:
Mawblei B., U. K. Sahoo, F. I. Musa, and Ramtharmawi, "Comparative study of physiochemical properties and microbial population in forest and shifting cultivation soil in Mizoram, India," *Journal of Sylva Indonesiana*, Vol. 08, No. 01, pp. 59-70 Feb. 2025, doi: 10.32734/jsi.v8i01.19339

ABSTRACT

Forest loss due to shifting cultivation (jhum) is believed to have intensified in recent years, primarily due to increasing population pressures and shorter fallow cycles. This study aims to examine the physiochemical properties and microbial population in forest soil and soil under shifting cultivation (jhum) in Mizoram, India. Soil samples were collected randomly in forest and shifting area using three depths (0 – 15 cm, 16 – 30 cm and 31 – 45 cm). Forest soil exhibited higher nitrogen (N) level, organic carbon content, moisture content and microbial diversity compared to shifting cultivation soil, which showed slightly higher phosphorus (P) level and comparable potassium (K) concentrations. Correlation revealed that forest soil had lower bulk density and higher water-holding capacity, linked to their enhanced organic matter and microbial activity. Additionally, shifting cultivation was associated with soil compaction, reduced nutrient availability and lower microbial populations, highlighting the negative impact of land-use change on soil health and ecosystem functioning. Moreover, these findings emphasize the need for sustainable land management practices to mitigate soil degradation and support soil fertility in shifting cultivation system.

Keyword: Forest Soil, Microbial Diversity, Shifting Cultivation, Soil Fertility, Soil Properties

1. Introduction

Northeastern Himalayan (NEH) region of India features distinct agro-ecological conditions, making it a center for the speciation of numerous plant species [1]. It is one of the twelve global biodiversity hotspots, with 65% of its area covered by forests and 16% used for agriculture [2]. The predominant agricultural practice and main source of income in the NEH is shifting cultivation, locally referred to as jhum [3]. Forests generally act as sinks for CO_2 and contain a significant pool of organic carbon (OC) [4] and variations in nutrient budgets, particularly carbon (C) and nitrogen (N), affect forest carbon fluxes [5]. However, understanding how variations in carbon exchange (as either a sink or source) within forest ecosystems are related to climate [6] and human activities is essential for evaluating nutrient dynamics across forested areas [7]. This information can serve as a baseline for predictive modeling, which can provide insights into future carbon fluxes at various scales. Additionally, comprehending CO_2 dynamics aids in developing effective climate change mitigation strategies [8,9]. For instance, forest conservation can enhance net biomass growth, increasing carbon sequestration potential [10].

Forest loss due to jhum cultivation is believed to have intensified in recent years, primarily due to increasing population pressures and shorter fallow cycles [11,12]. Over the past two decades, land-use conversion, particularly from natural to cultivated ecosystems, has been widespread, especially in tropical regions [13,14].

Shifting cultivation is a traditional farming technique that generally involves cycles of burning and clearing forests (primary or secondary), cultivating for a brief period, and subsequent abandonment of the site to allow vegetation to regenerate [15]. Some intellectuals argue that with the necessary and effective reforms, the continuation of shifting cultivation can cause minimal damage to soil erosion, as the high humidity and heavy rainfall in the region prevent the soil from remaining bare for long [16,17]. However, shifting cultivation has also been reported to reduce soil microbial biomass [18], which in turn diminishes certain enzymatic activities essential for soil health and functioning [19]. The adoption of non-traditional methods and crops by shifting cultivators has shortened the cultivation cycle from 15−20 years to 2−3 years [20]. This forces farmers to return to the same land more frequently, undermining the sustainability of this farming method, leading to the loss of topsoil. The process of re-vegetating fallow lands after shifting cultivation is typically slow and does not effectively restore soil microorganisms [21]. Extensive research has been conducted on the impact of land-use changes on soil carbon (C) and nitrogen (N) dynamics, given their potential effects on soil fertility and greenhouse gas emissions [22].

The conversion of natural forests to agricultural lands is known to result in soil C and N loss due to various factors such as reduced biomass input, disturbances caused by tillage, diminished soil aggregation, decreased physical protection of organic matter, and increased soil erosion [23,24]. Additionally, the transformation of primary broadleaf forests into plantations and secondary forests alter soil microbial communities and carbon-cycle genes, leading to reduced fungal richness, shifts in microbial composition, and decreased abundance of carbon-cycle genes associated with key processes like carbon fixation and degradation [25]. Significant differences exist in microbial populations between forest soils and those under shifting cultivation in India. Forest soils harbor diverse microbial communities crucial for ecosystem functions such as litter decomposition and soil formation. A decrease in soil organic matter and soil organic carbon values is noted with increasing depth [26]. Therefore, this study aims to compare physiochemical properties and microbial population in shifting cultivation and forest soils. The findings of this research underscore the distinct microbial dynamics between forest soils and those under shifting cultivation practices in India, underscoring the importance of comprehending and monitoring microbial populations in various land use scenarios for effective soil management and ecosystem sustainability.

2. Research Method

2.1 Study Area

The soil samples were collected from the forests of Mizoram University Campus. The study site is located at 23º44’13.93 N latitude and 092º39’39.88 E longitude and lies at an elevation of 760 m. While soil of the shifting cultivation was collected from the jhum fallow land at Tanhril village, Aizawl district of Mizoram (Figure 1). The jhum land site is surrounding by tropical semi-evergreen forests. The climate is humid and tropical, characterized by short winters, and long summers with heavy rainfall. The average temperature ranges from 13-36˚C and the average annual rainfall is about 2015 mm (based on the data for the last five years, 2020-2024). The site has been left fallow since 2019.

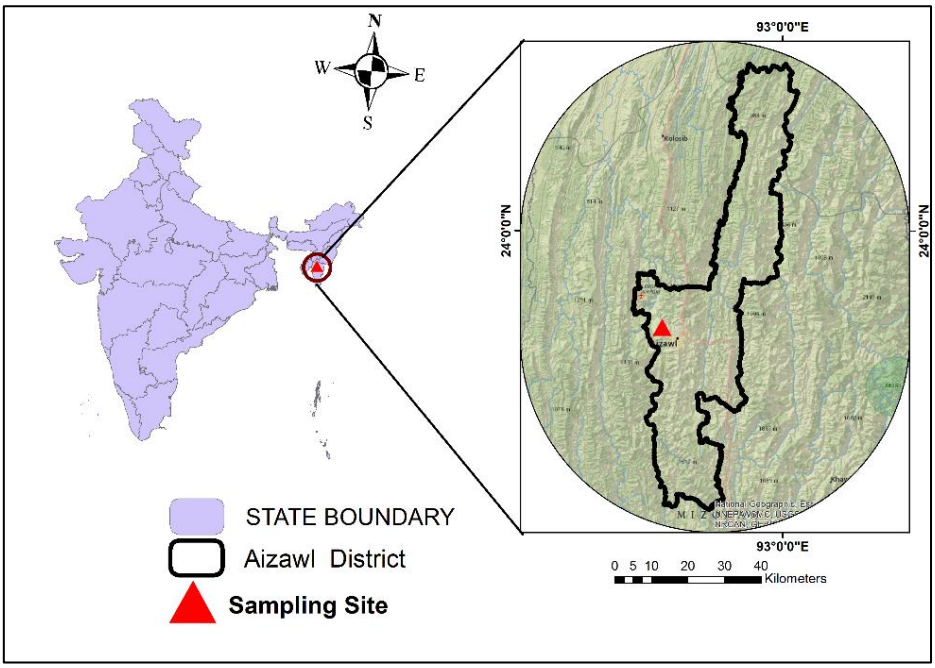

Figure 1. Study sites

2.2 Soil Collection and Analysis

The soil samples (approximately 500g) were collected randomly using a soil Auger from both the jhum fallow and forest sites in February, March, April, and May 2024. Soils were collected at 3 different depths i.e. 0 - 15 cm, 16 – 30 cm, and 31 – 45 cm from 5 randomly selected plots. The soil samples are then pooled together to make a composite sample of each depth. Subsequently, the collected soil samples were hand-sieved through a 2mm mesh where debris, stones, and roots were separated. Half of the samples (approximately 250g) were air-dried, and the other half were stored directly at -20˚C in a refrigerator. The soil for bulk density analysis was collected separately from both the land use system at different depths with the help of a soil core sampler.

2.3 Soil Moisture Content

Soil Moisture Content (SMC) was determined by a gravimetric method on a dry weight basis where 10g of fresh soil samples were taken on a Petri dish followed by drying in a hot-air oven at 105 ºC until constant weight. Then, oven dry weight was taken and recorded, and the moisture content was expressed as a percentage of the dry weight.

$$Moisture\ Content\ (\%) = \frac{Fresh\ weight - Oven\ dry\ weight}{\text{Oven dry weight}} x100\ [27] \quad (1)$$

2.4 Soil pH Value

The pH of the soil sample was determined by a combined glass electrode, using an instrument known as a pH meter in suspension of soil: water ratio of 1:2.5, where 10 g of fresh soil samples were taken in a beaker and added 25 ml of distilled water and shaken for 15-30 minutes. The mixture was left undisturbed for 24 hours as well as a pH meter was used for pH value reading.

2.5 Bulk Density

Bulk density was measured by collecting a known volume of soil using soil core and the weight was determined after drying for 6 hours in an oven with a set temperature of 105 ºC.

$$Bulk\ density = \frac{Dry\ weight\ of\ the\ soil}{\text{Volume of the soil}}\ [28] \quad (2)$$

2.6 Soil Water Holding Capacity (WHC)

Soil water holding capacity was determined by using fresh sample soil after the removal of gravel by percolation method. For the purpose, 20 g of soil sample was weighed and placed in a beaker and 40 ml of water was added in the beaker. WHC was estimated as the difference between the amount of water added and

the amount collected in the cylinder, divided by the initial weight of the dry soil, and then multiplied by 100% to express it as a percentage.

$$WHC(\%) = \frac{Amount\ of\ water\ added - Drainage\ collected}{\text{Dry soil weight}} x100 \text{ [29]} \quad (3)$$

2.7 Soil Organic Carbon (SOC)

Soil organic Carbon was determined following the method described by [30]. The SOC content in the soil is expressed in g (100g) -1 soil (%). 0.5g of air-dried soil was weighed and placed in a 500 ml conical flask and 10 ml of 1N $K_2Cr_2O_7$ followed by 20 ml concentrated H_2SO_4 was added and swirl, the mixture was kept for 30 minutes. Additionally, 100 ml of distilled water was added with 5 ml orthophosphoric acid followed by 1 ml diphenylamine indicator that gives dark blue colour and titrated with 0.5N ferrous ammonium sulphate (FAS) till it changed to parrot green colour.

$$100\text{g Soil Organic Carbon content } (\%) = \frac{(\text{Blank} - \text{sample reading}) \times 0.5 \times 0.003 \times 100\text{g}}{\text{sample weight}}$$

$$= \frac{Ag}{100\text{ g soil } (\mu g/100\ \mu g)}$$

$$\text{Organic matter content } (\%) \text{in soil} = \text{A x } 1.724 \text{ [30]} \quad (4)$$

2.8 Nitrogen (N)

Nitrogen was determined by the alkaline permanganate method of stated by [31]. 5g weight of air-dried soil was taken in a digestion tube and 40 ml $KMnO_4$ and 40 ml NaOH was added, and one spoon of paraffin wax was added and distilled for 6 minutes and collecting it in 2% Boric acid in a conical flask (dark green color). The sample was titrated with 0.1 N standard H_2SO_4 until the colour changed back to the original pink colour. Blank reading is taken for available N content without soil.

$$\text{N in kg/ha} = \frac{R \times 0.1 \times 0.014 \times 2.24 \times 10^6}{Soil\ taken\ in\ g} \quad (5)$$

2.9 Phosphorus (P)

Phosphorus was determined following the method described by [32], *P*1 method in which P content in soil is expressed in terms of kg ha-1 basis. However, 5g air-dried sieved soil was weighed and kept in a 250ml conical flask and 50ml extractant was added, shaken for 5 minutes, and filtered through Whatman no 42 filter paper for aliquot. 5 ml aliquot was taken in a 25 ml volumetric flask where 5 ml of Bray's reagent was added followed by 1 ml stannous chloride. The intensity of color can be measured by using a spectrophotometer at 660nm after the volume was made up to 25 ml with distilled water.

$$\text{Available P kg/ha } = \text{Con. of P } \times \text{ dilution factor } \times 2.24 \times 106/106 \text{ [32]}$$

$$\text{P2O5kg/ha} = \text{P} \times 2.29 \quad (6)$$

2.10 Potassium (K)

Soil available Potassium was determined by normal neutral 1 N ammonium acetate extractant, adjusting the pH to 7.0 using flame photometer [33]. Reagents: 1 N neutral ammonium acetate (7.0 pH): dissolve 77.08 g of ammonium acetate dissolved in 800 ml of distilled water and pH is adjusted to 7.0 with ammonium hydroxide or acetic acid and make the final volume to 1 litre. 5 g weight of soil in 100 ml conical flask and add 25 ml of Ammonium acetate solution. The solution was shake using the mechanical shaker for 20-30 minutes and then filtered. The aliquot is made up to a volume of 25 ml and potassium was determined using flame photometer.

$$\text{K2O (kg/ha)} = \frac{Conc.of\ K\ (pmm) \times \text{volume of the extractant (ml)} \times 2.24 \times 1.21}{Weoght\ of\ soil\ (g)} \quad (7)$$

2.11 Microbial Population (Bacteria and Fungi)

The soil microbial population was quantified by employing 1 g of freshly collected soil samples using the serial dilution technique described by [34]. A soil sample weighing 1 g was introduced into a test tube holding an initial volume of 10 ml of distilled water, resulting in a dilution ratio of 10-1. After thorough mixing, 1 ml

solution from the initial test tube was transferred to the following test tube, which contained 9 ml of distilled water and was labelled as having a dilution factor of 10^{-2}. The same procedure was performed to obtain dilution factors of 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} and 10^{-7}. The dilution plate technique experiment was conducted to obtain colony-forming units for the enumeration of microbial population, following the method described by [35]. Additionally, bacterial population was accessed using nutrient agar media. The Potato Dextrose Agar (PDA) combined with antibiotics (0.08 % of penicillin and chloramphenicol) along with a pinch of rose Bengal was used to access the fungi population. After preparing the media, 1 ml of each dilution was added to petri plates containing prepared medium. Subsequently, the plates were then incubated at a temperature of 28±10 ˚C for fungi and 25±10˚C for bacteria. The population count for bacteria was conducted after 24 hours of incubation completion, but for fungi, it was cultured for 72 hours before the population count. The plates were examined after the incubation period, and the number of colonies formed was quantified using a colony counter. The microbial population was examined and quantified as a colony-forming units per ml (CFUml-1).

$$\mathrm{CFUml}^{-1} = \frac{No.of\ colonies \times \text{dilution factor}}{Volume\ of\ culture} \tag{8}$$

3. Results and Discussion

3.1 Moisture Content

Moisture content of the forest soil was consistently higher than the moisture content of the shifting cultivation soil at all three depths (Figure 2). This suggests that forest soil is better at retaining moisture than shifting soil. The moisture content of the soil at all depths was less in February and March compared to April and May. The moisture content in April and May increased due to the beginning of rainfall. These findings confirm with [36] where soil moisture content was closely linked to seasonal changes in precipitation. Additionally, forest soils had greater porosity and organic matter content, which improved moisture retention compared to soils in disturbed areas such as those under shifting cultivation [37]. However, during the observation months (February – May 2024), the recorded rainfall varied significantly influencing soil moisture content. The increasing trend in rainfall contributed to the observed rain in moisture content from March to May. Additionally, rainfall patterns were relatively consistent across the observation site, with no significant variations in precipitation between two sites. However, differences in soil structure and vegetation cover influenced the retention and infiltration of water leading to distinct moisture retention capacities between the two soil types.

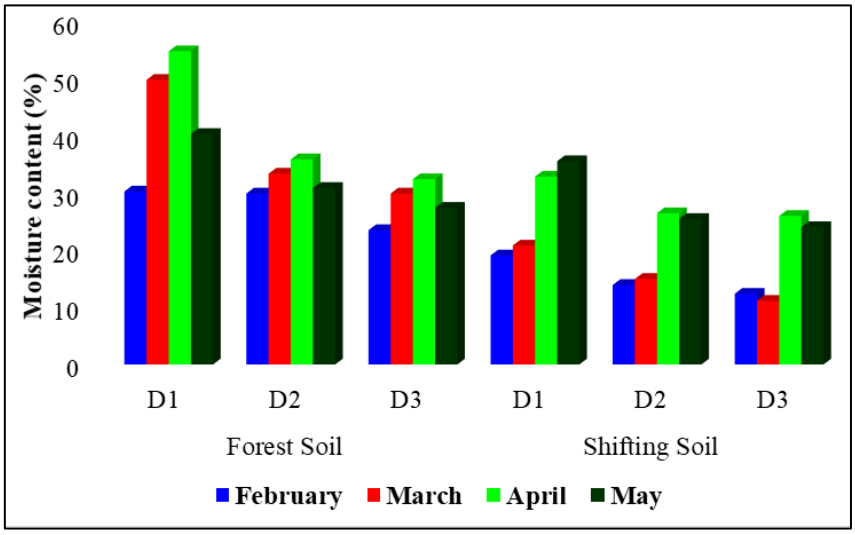

Figure 2. Moisture content of forest and shifting cultivation soil over 4 months (where D is depth; D1: 0 – 15 cm, D2: 16 – 30 cm, D3: 31 – 45 cm)

3.2 Water Holding Capacity

In both forest and shifting cultivation soils, the shallowest depth (D1, 0-15 cm) had the highest water-holding capacity, followed by D2 (16-30 cm) (Figure 3). Also, forest soil had a higher water-holding capacity compared to shifting cultivation soil. Additionally, the areas with higher water holding capacity may derive this property from soil structure and its capability to conserving water. However, the topsoil layer (0-15 cm)

had significantly higher water-holding capacity compared to deeper layers, attributed to higher organic matter and root presence [38]. Moreover, a study by [39] found that soil moisture and water-holding capacity typically increase during the rainy season due to higher precipitation, while [40] highlighted that forest soils have higher organic matter and better structure, which significantly enhance their water-holding capacity compared to soils subjected to shifting cultivation.

3.3 Soil pH, Bulk Density and Soil Organic Carbon

Soil pH is a measure of how acidic or basic the soil is. The forest soil was found to be more acidic than the shifting cultivation soil across all depths and measurement times (Table 1). The forest soil readings range from as low as 4.05 in February to as high as 5.25 in May. The shifting soil readings range from a low of 4.10 in February to a high of 5.11 in April (Table 1). Similarly, a study by [41] found that forest soils tend to be more acidic due to higher organic matter decomposition rates and organic acid production. Additionally, bulk density is influenced by the texture of the soil, the amount of organic matter in the soil, and the pore space in the soil. Although higher bulk density indicates less pore space and can restrict plant growth. In the present study, the bulk density of the forest soil was found consistently lower than that of the shifting cultivation soil across all depths and measurement times. This suggests that the forest soil has a greater amount of pore space than the shifting soil.

These findings are in agreement with other researcher [42,43] who reported that, forest soils have lower bulk density due to higher organic matter and better soil aggregation. Moreover, soil organic carbon (SOC) is the organic matter in the soil [44]. SOC improves soil structure, fertility, and water-holding capacity [45]. However, it was observed that the soil organic carbon in both forest and shifting cultivation soils decreased as the depth increased (Table 1). Moreover, the forest soil has a higher SOC content compared to shifting cultivation soil across all depths (Table 1). Further, SOC content was found significantly decreased with increase soil depth across various ecosystems [46] while [47] highlighted that forest soils maintained higher SOC levels due to sustained organic inputs and minimal disturbance.

The study sites experienced varying rainfall intensities during the observation period, with total monthly precipitation recorded as 15.2 mm (February), 33.8 mm (March), 87.0 mm (April) and 519.0 in (May). These rainfall pattern influenced pH and soil organic level by affecting decomposition rates and leaching processes. Conversely, increased rainfall in May contributed to enhanced organic matter decomposition in the forest soil leading to more acidic conditions compared to shifting cultivation soil. Moreover, variations in vegetation cover played a key role in soil structure and organic carbon content. The forest site predominantly contained native tree species such as *Schima wallichii, Castanopsis indica, Shorea robusta, Albizia chinensis, Albizia procera*, and other tree species, along with undergrowth vegetation. In contrast, the shifting cultivation site was dominated by grasses, seasonal crops, which contribute lower organic matter input compared to the continue litterfall in forests. Therefore, these differences in plant cover significantly influenced bulk density, with higher values in shifting cultivation soil due to compaction and reduction of organic matter.

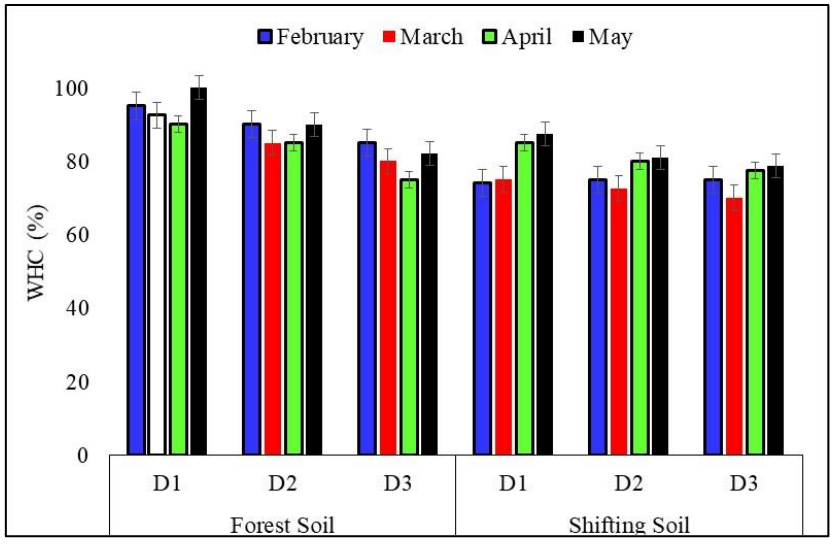

Figure 3. Water holding capacity of forest soil and shifting soil over 4 months

Table 1. Soil pH, bulk density, and soil organic carbon of forest and shifting cultivation soils

Soil Characteristics/Depth		Forest Soil			Shifting Soil		
		D1 (0 - 15 cm)	D2 (16 – 30 cm)	D3 (31 – 45 cm)	D1 (0 – 15 cm)	D2 (16 – 30 cm)	D3 (31 – 45 cm)
Soil pH	February	4.05	4.70	4.80	4.20	4.40	5.10
	March	4.90	4.70	5.00	4.10	4.00	4.40
	April	5.25	4.84	4.74	4.86	4.95	5.11
	May	5.25	4.84	4.74	5.00	4.90	5.10
Bulk Density	February	1.26	1.32	1.40	1.38	1.41	1.44
	March	1.25	1.30	1.38	1.39	1.40	1.42
	April	1.21	1.20	1.35	1.33	1.36	1.39
	May	1.20	1.27	1.34	1.32	1.35	1.38
Soil Organic Carbon	February	1.96	1.22	0.98	0.45	0.45	0.27
	March	1.41	1.14	0.73	0.59	0.46	0.46
	April	2.17	1.53	1.03	1.53	0.13	1.23
	May	2.15	1.50	1.02	1.50	1.25	1.22

D is depth; (D1: 0 – 15 cm, D2: 15 – 30 cm, D3: 30 – 45 cm).

3.4 Bacteria and Fungi Populations in Forest and Shifting Cultivation Soils

Bacteria colony-forming units (CFU) per millilitre is a measure of the number of viable bacteria in a millilitre of soil. The bacterial population in both forest soil and shifting cultivation soils was found in decreasing order with the increase in soil depth. Besides, the bacterial count in the forest soil was consistently higher than in the shifting cultivation soil across all depths (Table 2). Similar findings were reported by others [48,49] who found that microbial biomass, including bacteria, significantly decreases with soil depth due to reduced availability of organic carbon and nutrients. Furthermore, forest soils support higher microbial biomass and activity compared to disturbed soils e.g. agricultural land [50,51]. The tropical forest of Northeast India is reported high microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) in the forest floor, reflecting a robust microbial community that enhances soil fertility [52].

The fungal population in both forest soil and shifting cultivation soils was also found in decreasing order with the increase in soil depth. Besides, it was observed that the fungal count in the forest soil is consistently higher compared to shifting cultivation soil across all depths (Table 2). However, [53] demonstrated that fungal biomass and diversity decrease with soil depth due to lower organic carbon availability. Also, the study by [54] supports that forest soils have higher fungal biomass and diversity compared to soils subjected to agricultural practices, such as shifting cultivation. Conversely, microbial communities, particularly fungi and bacteria play a crucial role in soil fertility by contributing to organic matter decomposition, nutrient cycling and soil structure stability. The forest site with dense tree covers and diverse understory vegetation, provides a stable habitat for bacteria and fungi, facilitating nutrient cycling and organic matter turnover.

Our study shows that forest soil harbors a higher microbial population compared to shifting cultivation soils, which correlates with increase organic carbon and nitrogen content. However, bacteria facilitate nitrogen mineralization and organic matter decomposition, enhancing nutrient availability, while fungi especially mycorrhizal species improve phosphorus uptake and soil aggregation. The lower organic microbial population in shifting cultivation soils indicates reduced biological activity, likely due to soil compaction, lower organic matter input and periodic disturbances from cultivation practices.

Table 2. Bacteria and fungi populations between forest and shifting cultivation soils

Soil Characteristics/Depth		Forest Soil			Shifting Soil		
		D1 (0 - 15 cm)	D2 (16 - 30 cm)	D3 (31 - 45 cm)	D1 (0 - 15 cm)	D2 (16 - 30 cm)	D3 (31 - 45 cm)
Bacteria (CFU/ml)	February	11333.3	5266.6	2133.3	4333.3	3533.3	1400.0
	March	11433.0	5400.0	2000.0	4400.0	3333.0	1466.6
	April	11933.3	5666.6	2200.0	5000.0	3666.6	1733.3
	May	12000.0	5766.6	2100.0	5200.0	3733.3	1433.3
Fungi (CFU/ml)	February	3000.0	666.7	266.7	1500.0	300.0	166.7
	March	3066.0	633.3	366.6	1533.0	500.0	233.0
	April	6166.0	466.0	300.0	1900.0	333.3	200.0
	May	6000.0	500.0	266.0	1900.0	233.3	200.0

3.5 Correlation Between Soil Parameter in Forest and Shifting Cultivation

We observed a strong negative correlation between the soil pH and bulk density. This suggests that lower bulk density soils (indicative of higher porosity) are associated with higher pH level (Table 3), as also observed by others [55,56]. Although, acidic soils often have higher compaction, which reduce microbial activity and nutrient cycling. Conversely, soils with neutral to alkaline pH tend to exhibit greater aeration and porosity, facilitating microbial activity and nutrient availability. However, bulk density with organic carbon, showed the inverse relationship between bulk density and organic carbon reflects the structural benefits of organic matter in reducing soil compaction (Table 3). In mean time, organic matter improves soil aggregation and porosity, enhancing water retention and infiltration. Consequently, higher WHC and moisture content are also associated with lower bulk density, as porous soils hold more water. Therefore, this highlights the critical role of organic carbon in improving soil physical properties and mitigating compaction in cultivated system. The negative correlation between bulk density and microbial population (bacteria and fungi) is consistent with hypothesis, impeding microbial respiration and proliferation. Additionally, in contrast, lower bulk density soils provide a more favourable environment for microbial growth due to improved aeration and nutrient diffusion.

Our results also showed positive correlations between soil pH with organic carbon, WHC, and moisture content (Table 3). The higher pH levels are strongly linked to increased organic carbon, WHC and moisture content. However, this synergy likely arises from the ability of neutral to alkaline soils to support diverse microbial communities that contribute to organic matter decomposition and humus formation, enhancing water retention and moisture availability. Additionally, the positive association between organic carbon, WHC and moisture content underscores the pivotal role of organic matter in improving soil hydrological properties. Besides, organic matter increases soil porosity and acts as a sponge, retaining water and supporting microbial habitats [57]. In mean time, the positive correlation between soils moisture and water holding capacity exhibit a greater capacity to retain moisture, ensuring better water availability for plant and microbes. This relationship underscores the interconnectedness of soil physical and biological properties in promoting soil health. Furthermore, the strong positive correlation between microbial population and soil organic carbon, moisture content and pH demonstrate that microbial activity thrives in environments with optimal nutrient availability, moisture, and neutral to slightly alkaline pH [57]. However, organic matter serves as a primary energy source for microbes, while adequate moisture and pH provide a conductive environment for their metabolic factions.

In shifting cultivation sites, similar pattern of correlations were observed. However, the negative relationship between bulk density and other soil properties (pH, organic carbon, WHC, and moisture content) (Table 3) align with the findings from non-cultivated soils, suggesting that cultivation practices leading to soil compaction negatively impact soil health. Conversely, the positive correlations among pH, organic carbon, WHC, and microbial population indicate that these properties are interdependent and critical for maintaining soil fertility and productivity in shifting systems. Moreover, shifting cultivation likely alter soil structure and organic matter dynamic, likewise the positive associations highlight opportunities for sustainable land management. For example, enhancing organic carbon inputs through crop residues or cover crops can mitigate soil compaction, improving moisture retention and microbial populations.

Table 3. Correlation between soil properties in forest and shifting cultivation soil (MC: moisture content, BD: bulk density, SOC: soil organic carbon, WHC: water holding capacity, B: Bacteria (CFU/ml) and F: Fungi (CFU/ml))

Site		pH	MC	BD	SOC	WHC	B	F
Forest soil	pH	1						
	MC	0.79	1					
	BD	-0.82	-0.66	1				
	SOC	0.23	0.00	-0.71	1			
	WHC	-0.45	-0.90	0.41	0.10	1		
	B	0.76	0.44	-0.96	0.80	-0.15	1	
	F	0.74	0.46	-0.97	0.83	-0.20	1.00	1
Shifting cultivation soil	pH	1						
	MC	0.90	1					
	BD	-0.86	-0.99	1				
	SOC	0.81	0.93	-0.98	1			
	WHC	0.97	0.97	-0.96	0.94	1		
	B	0.93	1.00	-0.98	0.92	0.98	1	
	F	0.44	0.78	-0.78	0.71	0.61	0.75	1

3.6 Nitrogen, Phosphorus and Potassium in Forest and Shifting Cultivation Soil

The NPK values of forest and sifting cultivation soils are shown in Table 4. The results show higher nitrogen level in forest soil compared to shifting cultivation sites and similar findings have been recorded several researchers [58]-[60], This difference between the two study sites may be attributed to the organic matter from litter fall in forest and root turnover, which contributing to nitrogen accumulation through mineralization, although land disturbance in shifting cultivation disturbs soil structure and organic matter lead to nitrogen loss through leaching, erosion and volatilization. However, the lower nitrogen level in shifting cultivation sites may result in nutrient deficiencies, potentially limiting crop productivity unless supplemented by external inputs. Additionally, phosphorous level is slightly higher in shifting cultivation soils, which could be due to phosphorus release from mineral weathering or residues from burning biomass during land clearing. However, phosphorus availability in tropical soils is often limited by fixing iron and aluminum oxides, and the relatively small difference between the systems indicated that P available remains constrained in both cases. Conversely, the effort to improve phosphorus management in shifting cultivation systems should focus on practices such as incorporating phosphorus-rich organic amendments or phosphorus-solubilizing microbes to enhance its bioavailability.

Moreover, potassium levels are similar between forest and sifting cultivation sites, suggesting that this nutrient is less affected by land-use change compared to nitrogen. However, the slightly lower potassium levels and wider variability in shifting cultivation soils may reflect nutrient depletion over time due to crop uptake and leaching, particularly in the absence of the replenishment. Therefore, to sustain productivity in shifting cultivation systems, practices such as integrating potassium-rich organic inputs or maintaining soil cover to reduce leaching are essential.

Table 4. Statistical analysis of soil in forest and shifting soil of different months and depth level

Statistics	Forest			Shifting		
	N	P	K	N	P	K
Mean	543.67	80.98	212.00	420.17	83.87	209.17
Standard Error	43.54	2.25	32.42	43.27	1.42	34.90
Standard Deviation	106.64	5.51	79.42	106.00	3.47	85.49
Minimum	464.00	70.80	159.00	351.00	78.90	124.00
Maximum	715.00	87.10	363.00	627.00	87.30	345.00

4. Conclusion

A significant difference in the physiochemical properties and microbial diversity was noticed between the forest and shifting cultivation soils across the various depths and measuring period. However, the forest soil had a more diverse microbial population as compared to the shifting cultivation soil. This suggest that the fertility of the forest soil is more compared to shifting cultivation soil. Moreover, both soil types exhibited changes in their properties and microbial diversity with depth and over different measurement periods, reflecting the dynamic nature of soil ecosystems and their responses to environmental factors.

Acknowledgement

First author (B. M.) thanks Dr. Deity Gracia Kharlukhi for helping him to select the research topic and support.

Conflict of Interest

The authors declare that they have no conflict of interest.

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