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Land Use Change Effects on Soil Physical and Biochemical Properties during Wet and Dry Season in Forest and Shifting Cultivation (*Jhum*) Sites in Northeast India

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ABSTRACT

Land use change is among the most serious concern in northeast India because of widespread practiced shifting cultivation locally called "*Jhum*". This practice involves slashing and burning of plant biomass in a piece of forest land and cropping for few years (ca. 1-2 years) followed by land abandonment for 5-30 years to resume soil fertility. This study assesses the changes in soil physico-chemical and biochemical properties in forest and *Jhum* land in wet to dry seasons in Mizoram, northeast India. A significant decrease in physico-chemical properties (e.g., 9-25%) and biochemical properties (15-39%) of soil in current *Jhum* land compared to forest land. This decrease was more pronounced in the dry period than in the wet period. The results showed that land use change negatively impacted the physico-chemical and microbiological properties of the soil. Notably, the transformation from forest to *Jhum* land led to a decline in soil organic matter stocks, which serve as a crucial ecological indicator for assessing changes in soil quality resulting from forest clearance or crop cultivation. Therefore, sustainable land management policies need to be developed keeping such things in mind, such as agroforestry and farm forestry, in which the farming system grows trees alongside agricultural crops and animals on the same land management units.

Keywords Shifting cultivation, Soil organic carbon, Nitrogen, Microbial biomass.

INTRODUCTION

Land use changes is among the most important problems occurring over the world, which is particularly noticed in different parts of northeast India, including Mizoram because of widespread practice of shifting cultivation locally called "*Jhum*" meaning work together. During the process of *Jhuming*, a piece of forest land is slashed during December - January, and the slashed biomass was burnt *in situ* in the month of February - March to release the nutrients locked in plant biomass to support cropping (Tripathi *et al.*

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2017, Ovung *et al.* 2021). Seeds are then sown in April-May. Generally, after a few years of cropping (i.e., 1-2 years) depending on the status of the soil fertility, when the crop production decreased due to reduced soil fertility the land is abandoned for few years (i.e., <5-30 years) to resume soil fertility through natural regeneration. The length of land abandoned period "fallow" was sufficient (e.g., 20-30 years) earlier, however, in recent years fallow length has been substantially reduced to about < 5 years (Wapongnunsang et al. 2017, Momin *et al.* 2021). This practice is commonly referred to as 'slash and burn' agriculture and is known as '*Jhum*' or '*Jhuming*' in North-East India.

Shifting cultivation is predominantly practiced at the individual or family level, although it can sometimes involve entire villages. This farming method is most prevalent among subsistence farmers in rural areas of Northeast India. Shifting cultivation is a widespread agricultural practice found in various parts of the world, particularly in the tropical rainforests of South America, Central and West Africa, and Southeast Asia (Grogan *et al.* 2012). The cultivation landscapes currently encompass approximately 280 million hectares globally, comprising both cultivated fields and fallow lands (Heinimann *et al.* 2017). This traditional farming method is commonly employed by tribal communities and supports the livelihoods of an estimated population exceeding 250 million people worldwide (Tripathi *et al.* 2017), although it often reported for adverse ecological consequences.

This practice of cultivation, often blamed for deforestation, relies on length of fallow periods to restore soil fertility instead of external inputs like fertilizers. Nutrients are cycled between natural vegetation and crops, and ecological equilibrium is maintained through diverse cropping systems, in contrast to monoculture. It is an ancient primitive crop cultivation method facing sustainability challenges due to a shortened cultivation cycle, now typically spanning 3-5 years, mainly caused by population pressure (Wapongnungsang *et al.* 2017). However, there is a contrasting concern in developing countries where sustaining a rapidly growing human population is a significant challenge due to land degradation. Soil, as a fundamental component of terrestrial ecosystems, is highly complex, comprising geological materials, organic matter, water, atmosphere, roots, animals, and microbes (Singh *et al.* 2020, Singh *et al.* 2022, Manpoong and Tripathi 2021). These components collectively determine the physical and chemical properties vital for plant growth and support various forms of life (Kimmins 1988). Managing soil quality depends on understanding soil responses to agricultural practices over time. Soil resources are increasingly recognized as vital for Earth's biosphere. Soil not only sustains food and fiber production but also plays a crucial role in environmental quality on local, regional, and global scales (Doran and Parkin 1994). Soil quality degradation is largely attributed to the destruction of forests and degradation of biological properties. Improper land use exacerbates soil physico-chemical properties (Saikh *et al.* 1998). The decline in soil health results from a combination of soil fertility and biological deterioration, leading to increased acidity, alkalinity, and exposure of compacted subsoil with poor physico-chemical properties (Wang *et al.* 2001).

Understanding the physico-chemical properties of soil is essential for informed land use planning. This study aims to assess soil physical and biochemical properties in forest (Forest) and shifting cultivation land (*Jhum*) and quantifies changes in these properties during wet and dry seasons. We hypothesize that the current practice of shifting cultivation with short fallow periods has a detrimental effect on soil properties, thereby reducing soil fertility and crop productivity.

MATERIALS AND METHODS

Study sites

The study sites were carefully chosen from two distinct land use types, namely, forest and *Jhum* land (Fig. 1). The forest site was identified within the Mizoram University campus (23º44'13.93" N and 092º39'39.88" E) at an elevation of 760 amsl. The site has characteristic tropical wet evergreen and semi-evergreen forest ecosystem (Champion and Seth 1968).

However, the shifting cultivation site (1 year old), was selected near Lengpui Airport, situated approximately 40 km northwest from Aizawl city

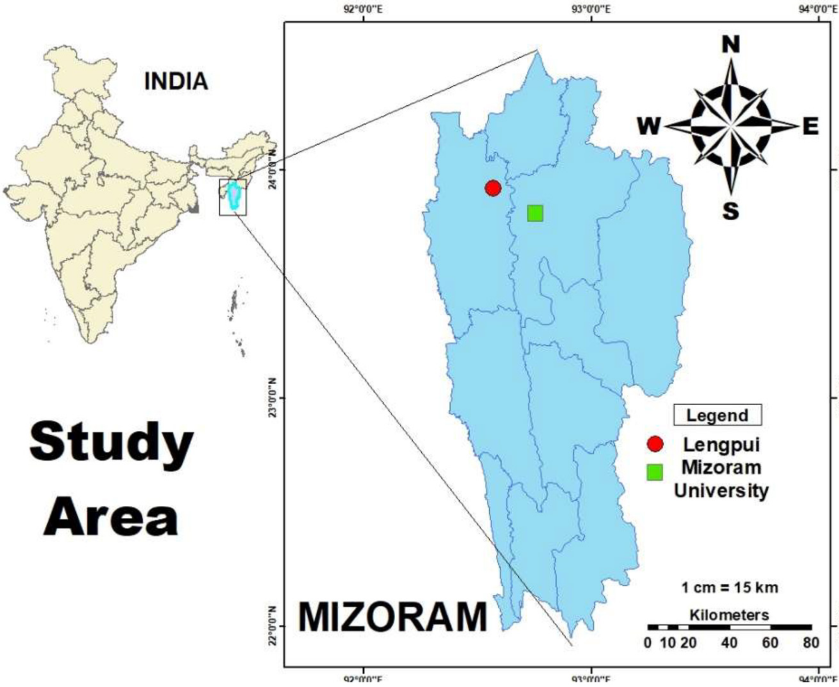

Fig. 1. Mizoram map indicating the study sites along with GPS coordinates.

in the Mamit district. The site is positioned on the outskirts of Lengpui village (23º50'05.15" N latitude and 092º37'05.68" E longitude) at an elevation of 426 amsl. The study sites at both places experience a humid subtropical climate with moderately hot and humid summers and mild winters.

Collection of soil samples

Soil samples were meticulously collected from the two sites using a soil corer with a diameter of 4.3 cm, obtaining samples at three different depths: 0-10cm, 10-20cm, and 20-30 cm. The wet season soil samples were collected in October 2018, while the dry season soil samples were obtained during February 2019. These samples were collected from five permanent plots, each positioned 15 to 20 meters apart. Subsequently, the collected soil samples were transported to the laboratory for a thorough physico-chemical analysis. To prepare them for analysis, the samples underwent a hand-sieving process using a 2 mm mesh sieve, which effectively separated debris, stones, and roots. To ensure comprehensive analysis, half of the collected samples were air-dried, while the other half were carefully stored at -20ºC for subsequent analyses.

Soil analysis in laboratory

A comprehensive analysis of various soil properties was performed using established methods. Soil Moisture Content (SMC) was determined gravimetrically, following the procedure outlined by Bandyopadhyay *et al.* (2012). To assess soil pH, we employed a digital pH meter, maintaining a soil-to-water ratio of 1:2.5 w/v. Bulk density was measured by collecting a known volume of soil using a soil corer, and subsequent weight determination followed a 6 hr drying period in a hot air oven at a temperature of 105ºC; the dimensions of the soil corer were recorded for volume calculations (Blake and Hartge 1986). Soil Water Holding Capacity (WHC) was assessed using the Keen-Raczkowski box method, utilizing fresh soil samples devoid of gravel (Coutts 1930). Soil texture analysis was conducted through the hydrometer method (Bouyoucos 1962), involving the use of 50g of air-dried soil (2mm sieved) in a beaker. The percentages of sand, silt, and clay were calculated, and textural classes were determined following the USDA classification. Additionally, we determined Soil Organic Carbon (SOC) using the rapid oxidation and titration method devised by Walkey and Black (1947). Organic matter (OM) content (%) in the soil was computed by applying a factor of 1.724. For available phosphorus (P_{avail}), we employed the Bray and Kurtz (1945) method, multiplying the result by 2.29 to obtain concentration of P as P_2O_5. Total nitrogen (TN) content in the soil samples was determined via the Kjeldahl Method of nitrogen estimation (Baethgen and Alley 1989). Concentration of ammonium nitrogen (NH_4-N) and nitrate nitrogen (NO_3-N) was determined using the indophenol blue method and the phenol di-sulphonic acid method, respectively. Microbial biomass carbons (MBC) were assessed using the chloroform fumigation extraction method, following the approach suggested by Jenkinson and Powlson (1976). Similarly, microbial biomasses phosphorus (MBP) in the soil were determined through the chloroform fumigation extraction method, as outlined by Vance *et al.* (1987).

Statistical analysis

All collected data underwent thorough statistical analysis. We applied ANOVA, followed by the Least Significant Differences (LSD) test, to compare the physical and biochemical soil characteristics between the two sites and across the two seasons, encompassing both wet and dry periods. To explore the relationships among various soil parameters in both forest and shifting cultivation site, we employed Pearson's correlation analysis. These analyses were conducted using MS-Excel and SPSS version 18.

RESULTS AND DISCUSSION

Soil physical properties

The percent moisture content (MC%) exhibited a significant difference ($p<0.05$) between the forest and *Jhum* sites (Table 1). During the wet season, MC% ranged from 36.2% to 40.9% across depths in the forest site, whereas it varied from 14.42% to 25.31% during the dry season. Likewise, MC% ranged from 27.9% to 33% in the wet season and 11.9% to 14.7% in the dry season (Table 1) in the *Jhum* site. Notably, in the *Jhum* site MC% decreased with depth during the wet season, which increased in the dry season. The water holding capacity (WHC%) at different depths ranged between 66% and 84% during the wet season and 64.5% to 77.7% during the dry season in the forest site. In the *Jhum* site, these values ranged from 61.3% to 72.7% in the wet season and 59.4% to 68.1% in the dry season (Table 1). Variations in water holding capacity across different land uses may arise from differences in clay and organic carbon

Table 1. Soil physical properties of forest and *jhum* land during wet (W) and dry (D) season (mean ± SE, n = 3). MC% = Moisture content percentage, WHC% = Water holding capacity percentage, BD = Bulk density.

		Soil physical parameters											
	Depth	MC%		WHC%		BD	% sand		% silt		% clay		Textural
Sites	(cm)	W	D	W	D	(g/cm^3)	W	D	W	D	W	D	class
Forest	0-10	40.9 ± 0.04	25.31 ± 0.04	66 ± 1.9	64.5 ± 0.5	0.98 ± 0.12	65 ± 1	69 ± 1	16.3 ± 0.5	14.6 ± 0.2	18.7 ± 0.5	16.4 ± 1.2	Sandy loam
	10–20	38.1 ± 0.02	18.2 ± 0.02	71.6 ± 1.9	71.5 ± 7.1	1.04 ± 0.06	63 ± 1	67 ± 1	17.6 ± 1.2	15.3 ± 0.5	19.4 ± 0.2	17.7 ± 0.5	Sandy loam
	20-30	36.2 ± 0.02	14.42 ± 0.02	84 ± 3.7	77.7 ± 3.6	1.13 ± 0.12	61.5 ± 0.5	65 ± 1	18.5 ± 0.3	15.7 ± 0.5	20 ± 0.8	19.3 ± 0.5	Sandy loam
Jhum	0-10	33 ± 0.04	11.9 ± 0.02	61.3 ± 2.3	59.4 ± 5.8	1.18 ± 0.4	70.5 ± 0.5	72 ± 2	13.3 ± 0.5	13.6 ± 1.2	16.2 ± 1	14.4 ± 0.8	Sandy loam
	10–20	29.5 ± 0.04	13.1 ± 0.02	68.4 ± 3.6	64.7 ± 0.6	1.27 ± 0.3	68.5 ± 0.5	70.5 ± 0.5	14.4 ± 1	13.8 ± 1	17.1 ± 0.5	15.7 ± 1.1	Sandy loam
	20-30	27.9 ± 0.02	14.7 ± 0.04	72.7 ± 1.7	68.1 ± 0.06	1.31 ± 0.1	66.5 ± 0.5	68.5 ± 0.5	15.1 ± 0.3	15.3 ± 0.5	18.4 ± 0.2	16.2 ± 1	Sandy loam

Table 2. Soil chemical properties of forest and *jhum* land during wet (W) and dry (D) season (Mean ± SE, n = 3). SOC% = Soil organic carbon, OM% = Organic matter percentage, TN = Total nitrogen, NO_3-N = Nitrate nitrogen, NH_4-N = Ammonium nitrogen, P = Available phosphorus, P_2O_5 = Phosphorus pentoxide.

		Soil chemical parameters															
Sites	Soil depth (cm)	pH		SOC (%)		OM (%)		TN (%)		NO_3-N (µg/g)		NH_4-N (µg/g)		$P_{avai.}$ (kg/ha)		P_2O_5 (kg/ha)	
		W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D
Forest	0-10	5.2± 0.02	4.9 ± 0.04	3.53 ± 0.08	3 ± 0.13	6.09± 0.14	5.14± 0.23	0.37± 0.2	0.32 ± 0.2	12.5± 0.004	9.7 ± 0.01	9.8± 0.002	3.7 ± 0.003	20.1± 0.04	19.9± 0.02	46.1± 0.09	45.5± 0.04
	10-20	5.3± 0.01	5.1± 0.02	3.18± 0.05	2.4± 0.11	5.48± 0.08	4.14± 0.18	0.34± 0.14	0.28 ± 0.2	11.3 ± 0.01	8.4 ± 0.01	8.1 ± 0.002	2.98± 0.004	19.3± 0.02	18.8 ± 0.02	44.2 ± 0.04	43 ± 0.04
	20-30	5.4± 0.04	5.2± 0.04	2.8± 0.03	2.07± 0.09	4.87± 0.05	3.57± 0.16	0.3± 0.05	0.21± 0.3	9.1 ± 0.01	5.6± 0.01	6.1 ± 0.003	2.3± 0.002	18.6± 0.06	17.9 ± 0.02	42.6± 0.15	41.1± 0.04
	$LSD_{0.05}$	0.10	0.08	0.19	0.38	0.33	0.65	0.90	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jhum	0-10	5.01± 0.01	5.5± 0.05	2.9± 0.03	2.12± 0.12	5.07± 0.06	3.65± 0.2	0.28± 0.05	0.19± 0.3	8 ± 0.01	5.75± 0.01	8.8 ± 0.001	3 ± 0.002	18.8± 0.06	17 ± 0.02	43.2± 0.13	38.9± 0.05
	10-20	5.07± 0.01	5.6± 0.02	2.7± 0.05	1.7± 0.07	4.69± 0.09	2.86± 0.12	0.25± 0.2	0.18 ± 0.09	6.7 ± 0.01	4.7± 0.01	7.3 ± 0.002	2.6 ± 0.005	17.7± 0.04	15.8± 0.01	40.6± 0.09	36± 0.03
	20-30	5.1± 0.02	5.8± 0.02	2.5± 0.14	1.5 ± 0.09	4.28± 0.24	2.5± 0.15	0.19± 1.4	0.16± 0.2	6.02 ± 0.01	3.7± 0.01	4.2 ± 0.001	1.9 ± 0.003	15.1± 0.01	13.1± 0.01	34.6± 0.03	30.03± 0.02
	$LSD_{0.05}$	0.03	0.09	0.30	0.32	0.52	0.55	0.98	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest vs *Jhum* $LSD_{0.05}$		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

content, as well as the heterogeneity of the parent material (Sathyavathi and Reddy 2004, Goyal 2009). The higher clay content and organic matter typically corresponds to greater water holding capacity, as confirmed by results (Table 1-2). Notably, the WHC capacity was significantly high in forest during the wet season at a depth of 20-30cm, reaching 84%. This site also exhibited the highest clay content at 20%. Further, the soil textural class remained consistent across all depths and both study sites, characterized as sandy loam, with a limited water holding capacity that reaches its saturation point relatively sooner compared to clay loam soil (Wapongnungsang *et al.* 2017, Manpoong and Tripathi 2021).

Bulk density (BD) ranged from 0.98 to 1.13 g cm^{-3} in forest and 1.18 to 1.31 g cm^{-3} in *Jhum*, as detailed in Table 1. The highest BD measurement was recorded at a depth of 20 to 30 cm, with a corresponding value of 1.31 g cm^{-3}. The results were in accordance with values for cultivated and forested lands in the region (Manpoong and Tripathi 2021). Current observations aligned with the findings of Brady and Weil (2002), who posited that BD tends to increase with greater soil depth, a trend consistently observed in both of our study sites. Moreover, a significant decrease in the percentage of sand content was observed with increasing soil depth, whereas the corresponding values silt and clay content increased. The higher BD observed in the *Jhum* land can be attributed to the lower organic matter content in the soil and the compaction of soil because of cultivation activities that affected the soil structure (Osman *et al.* 2013).

The highest sand content was observed in *Jhum* at a depth of 0-10cm during the dry season, while the lowest was recorded during the wet season in forest at the same depth. The high sand content in the top soil of *Jhum* land use may be attributed to the low levels of clay and organic matter content, as reported by previous studies (Dutta *et al.* 2017). Maximum silt content was observed in forest at the depth 20-30 cm during wet season while minimum in *Jhum* site during wet season (Table 1). Further, the highest clay content was recorded in forest at 20-30 cm depth during wet season, whereas minimum was noted in *Jhum* site at the depth of 0-10cm during dry season (Table 1). Overall soil texture was found to be sandy loam. Both silt and clay content exhibited an increasing trend with greater soil depth, which can be attributed to the process of illuviation as reported by other studies (Gupta and Tripathi 1992, Gupta and

Verma 1992, Dutta *et al.* 2017).

Soil chemical properties

The soil pH values in both forest and *Jhum* were consistently acidic in nature with higher acidity during the dry season compared to the wet season. However, *Jhum* exhibited more acidity than forest across all seasons and depths (Table 2), with pH values ranging from 4.9 to 5.8. The maximum pH value (5.8) was recorded in *Jhum* during the dry season at lower depth (20-30 cm), while the minimum (4.9) was observed in forest during the dry season at a depth of 0-10cm (Table 2). The soil acidity in both sites during all seasons and depths could be attributed to the leaching of calcium carbonate and exchangeable bases, especially under high rainfall conditions (Olego *et al.* 2021). Acidic soils often exhibit lower phosphorus availability, primarily due to the increased solubility of aluminum, a component of clay and silt particles at lower pH levels (Table 2). Elevated aluminum levels can trigger chemical reactions with phosphorus compounds, rendering them insoluble and unavailable to plants. However, the higher availability of phosphorus in forest land is likely to be influenced by a higher amount of organic matter, which releases organic anions upon decomposition. These organic compounds can form chelates with iron (Fe) and aluminum (Al), ultimately releasing available phosphorus (Najar 2002, Garcha *et al.* 2016, Maqbool *et al.* 2017). Additionally, mycorrhizal associations in tree roots may also enhance phosphorus solubilization.

The SOC% content exhibit significant difference ($p<0.05$) between the forest and *Jhum* sites. The values of SOC% showed a decreasing trend with increasing soil depth, ranging from 3.53 (0-10 cm) to 2.07 (20-30 cm) in forest and 2.9 (0-10 cm) to 1.5 (20-30 cm) in *Jhum*. The maxiumum SOC% (3.53) was observed in forest during the wet season at upper soil depth (0-10cm), whereas the minimum (1.5) was recorded in *Jhum* during the dry season at lowest soil depth (Table 2). The higher value of SOC in the forest land use system can be attributed to the addition of organic matter, primarily in the form of leaf and root litter. Soil organic matter undergoes microbial decomposition, affected by factors like soil moisture, temperature, and the type of organic input (Wang *et al*. 2010, Garcha *et al*. 2016, Wapongnungsang *et al.* 2017). Changes in soil pH are mainly attributed to this organic material decomposition, generating organic acids, including carbonic acid, gradually reducing soil pH. This observation is consistent with the findings of the current study, where both soil pH and soil organic carbon content (%) were significantly higher during both the wet and dry seasons at both forest and *Jhum*.

Further, the concentration of TN, NO_3-N, NH_4-N, P_{avail} and P_2O_5 exhibited similar trends, with significantly higher values during the wet season compared to the dry season and higher values in forest than in *Jhum* (Table 2). Difference was significant ($p<0.05$) between the forest and *Jhum* sites during wet and dry period. These chemical parameters show a decrease in their content with increasing depth. The elevated content of such chemical parameters in forest compared to *Jhum* can be attributed to greater vegetative cover and higher leaf litter accumulation. Caravaca *et al.* (2003) also reported the influence of herbaceous growth on nutrient input and development, particularly carbon and nitrogen, which are vital components of net primary productivity due to their high turnover rates and significant contribution to carbon and nutrient accumulations.

Soil microbial parameters

Ecosystems characterized by continuous inputs of organic residues, as observed in native forests or afforestation areas, tend to have higher levels of soil microbial biomass (Hackl *et al.* 2005). The depletion of essential organic nutrients such as nitrogen (N), phosphorus (P), and sulfur (S) in soils is primarily attributed to deforestation and the conversion of pristine forests into cultivated land—a hypothesis supported by various researchers (Garcha *et al*. 2016, Maqbool *et al.* 2017). Soil microbial biomass carbon (MBC) exhibited a notably higher concentration in forest compared to *Jhum*. This pattern further aligns with the trends observed in the chemical parameters, through higher values recorded during the wet season and lower values during the dry season. The elevated MBC levels in forest can be attributed to the presence of a relatively larger quantity and higher quality of leaf litter, which serves as a valuable carbon source, supporting a more extensive microbial community

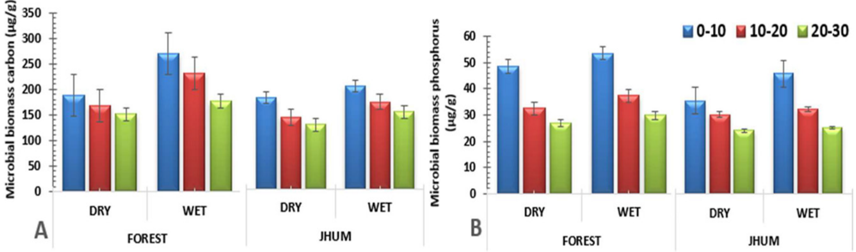

Fig. 2. Graphically representing (A) Soil microbial biomass carbon (MBC) and (B) Microbial biomass phosphorus (MBP) from both forest and *jhum* sites at different depths (0-10cm, 10-20cm and 20-30 cm) during wet and dry seasons.

both above and below the ground (Negassa and Gebrekidon. 2004).

The maximum value of MBC (270 µg/g) was observed in forest at upper soil depth (0-10cm) during the wet season (Fig. 2), which consistently decreased with increase in soil depth. The higher MBC content in the top soil of forest land during wet season is likely to be because of the microbial activity performed by soil decomposers involved in decomposition of soil organic matter (Wapongnungsang *et al.* 2017, Wapongnungsang and Tripathi 2019). This observation reinforces the concept that the increase in MBC is directly related to the rise in organic matter content, a phenomenon previously documented by Vance *et al.* (1987). Similarly, the MBP also exhibited higher values in forest during both dry and wet seasons. It is believed to be linked to higher amount of organic matter in forest ecosystem, which generates organic anions on decomposition leads to formation of chelates of Fe and Al leading to release of available phosphorous (Najar. 2002, Garcha *et al* 2016, Maqbool *et al*. 2017). Higher microbial biomass during the rainy season is attributed to increased immobilization of soil nutrients by microbes during organic matter decomposition (Yang *et al.* 2010, Hauchhum and Tripathi 2019). The decrease in soil microbial biomass with increasing soil depth is likely due to decreasing soil organic carbon content at greater depth (Franzluebbers *et al.* 1994, Wapongnungsang and Tripathi 2019). Soil microbial biomass is exceptionally responsive to even slight fluctuations in soil organic matter content, as it serves as a primary energy source. This aligns with the findings of Chen *et al.* (2005) and Wang and Wang (2007), who established a direct and linear correlation between total organic

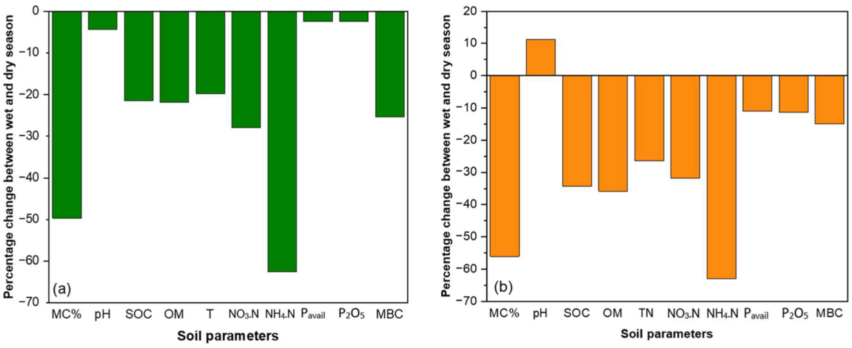

Fig. 3. Percent decrease in soil chemical properties in dry period compared to wet period in forest (a) and jhum land (b). MC% = Moisture content, SOC% = Soil organic carbon, OM% = Organic matter percentage, TN = Total nitrogen, NO_3-N = Nitrate nitrogen, NH_4-N = Ammonium nitrogen, P_{avail} = Available phosphorus, P_2O_5 = Phosphorus pentoxide, MBC = Microbial biomass carbon, MBP = Microbial biomass phosphorus.

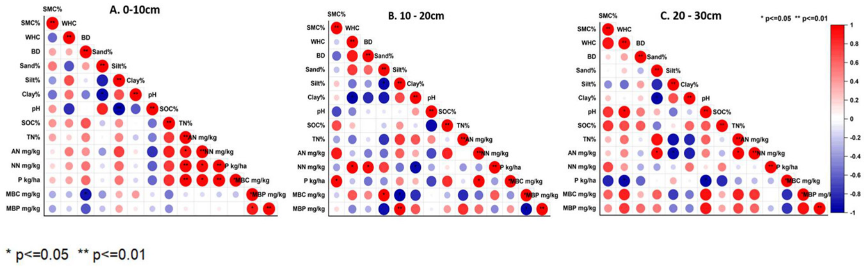

Fig. 4. Correlation between soil properties such as carbon and nutrient and microbial biomass in forest site. SMC, soil moisture content; WHC, water holding capacity, BD, bulk density, SOC, soil organic carbon; OM, organic matter; AN(NH_4-N) and NN(NO_3-N) soil extractable nitrogen ammonia and nitrate; P, available phosphorus; MBC, microbial biomass carbon; MBP, microbial biomass phosphorus of forest ecosystem at depth of (A) 0-10 cm, (B) 10-20 cm and (C) 20-30 cm.

carbon (TOC) and soil microbial biomass.

Changes in soil chemical and microbial properties during wet and dry seasons

A significant variation has been observed between different soil characteristics of the two land use systems during the wet and dry seasons. The soil nutrients (including SOC, OM, TN, NO_3-N, NH_4-N, P_{avail}, P_2O_5, MBC, MBP) exhibited considerable reduction during the dry season (Figs. 3a-b), which ranged from 2% to 63%. A substantial decrease (ca. 63%) was observed in NH_4-N followed by MC (49% and 56%) in forest and *Jhum* land. In contrast, pH and phosphate concentration in the soil exhibited minimal changes, with average alterations ranging from 10% to 35% in both locations (Fig. 3). Similar changes have also been reported by Hauchhum and Tripathi (2019) and Wapongnungsang and Tripathi (2019) from this region.

Correlation between various soil parameters

The relationship between various soil properties, including carbon, nutrients, and soil microbial biomass, in both forest and *Jhum* sites were presented in (Fig. 4 and 5). In the forest site, most of the parameters showed insignificant association (either positive or negative) except for total nitrogen which showed significant positive correlation with extractable nitrogen (NH_4-N and NO_3-N) and phosphorous (P_{avail}), and MBC with MBP at 0-10 cm depth. Further, at 10-20 cm depth, a positive significant relationship was observed between SMC and P, WHC and NO_3-N, BD and NO_3-N, sand and MBC and silt and MBP. At 20-30 cm depth, only WHC and sand showed positive significant correlation with pH and NH_4-N, respectively (Figs. 4A- 4C). Availability of nitrogen (NH_4-N and NO_3-N) and P_{avail} in the soil have been reported to vary with the amount of soil organic carbon and total nitrogen and total phosphorus contents in soils

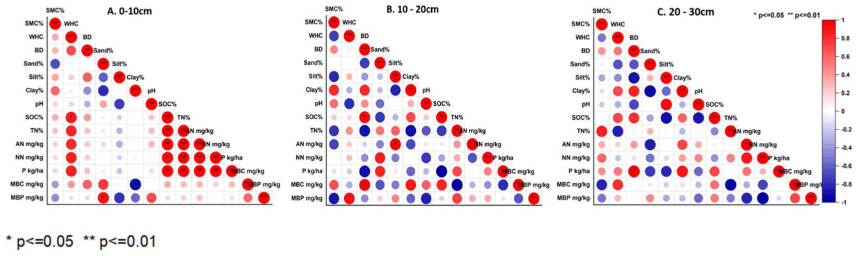

Fig. 5. Correlation between soil properties such as carbon and nutrient and microbial biomass in forest site. SMC, soil moisture content; WHC, water holding capacity; BD, bulk density; SOC, soil organic carbon; OM, organic matter; AN (NH_4-N)) and NN (NO_3-N), soil extractable nitrogen ammonia and nitrate; P, available phosphorus; MBC, microbial biomass carbon; MBP, microbial biomass phosphorus of *Jhum* ecosystem at depth of (A) 0-10cm, (B) 10-20 cm and (C) 20-30cm.

of different land uses at different depths (Hauchhum and Tripathi 2019, Wapongnungsang and Tripathi 2019, Singha *et al.* 2020).

In the *Jhum* site (0-10cm), a noteworthy positive relationship was observed between several factors: WHC and SOC, sand and MBP, and SOC, TN, NH_4-N, NO_3-N, and P_{avail}. Further at 10-20cm depth, BD exhibited noteworthy associations with SOC and MBC, and silt with NH_4^-N. In case of 20-30cm depth, only BD showed a significant positive correlation with P (Figs. 5 A-C). These soil properties have been reported to be interdependent on each other at different spatial gradients (Wapongnungsang and Tripathi 2019, Singha *et al.* 2020).

CONCLUSION

Present findings indicate a significant decrease in these properties during land conversion, particularly affecting soil organic matter—a critical ecological indicator reflecting changes due to conversion of forest land into cropping field. Considering the *Jhum* cultivation a primary livelihood option for many rural poor in Mizoram, the government may need to prioritize sustainable farming systems like agroforestry and farm forestry. These approaches involve the simultaneous cultivation of trees, crops, and animals within the same land units, offering great potential for enriching the soil nutrients. Notably, nitrogen-fixing trees and deep-rooted species, along with leguminous shrubs, play essential roles in enhancing soil organic matter and promoting soil health by fixing atmospheric nitrogen. Our study further reveals that forests consistently exhibit higher nutrient levels compared to *Jhum* land, with wet seasons generally showing higher values than dry seasons. Further research in the region is imperative to gain a more comprehensive understanding of these dynamics and their consequences.

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