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Soil properties under different land use systems of Mizoram, North East India

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Abstract
Changes in land use and improper soil management have led to severe land degradation around the globe through the modification in soil physicochemical and biological processes. This study aimed to assess the soil properties of different land use system types. Soil samples (0-15 cm depth) were collected from five land uses; Rubber Plantation (RP), Oil Palm Plantation (OPP), Bamboo Forest (BF), Fallow Land (FL) and Natural Forest (NF) and analyzed for bulk density, soil texture, soil pH, soil moisture, soil carbon, total nitrogen, ammonium, nitrate, soil microbial biomass carbon, soil respiration. Soil pH was lower than 4.9 in all the sites indicating that the surface soil was highly acidic. Soil organic carbon (SOC) and total nitrogen (TN) values ranged from 2.02% to 2.81% and 0.22% to 0.3% respectively. Soil organic carbon (SOC), total nitrogen (TN) and soil microbial biomass (SMBC) were highly affected by soil moisture. NH_4^+-N and NO_3^--N ranged from 5.6 mg kg^{-1} to 10.2 mg kg^{-1} and 1.15 mg kg^{-1} to 2.81 mg kg^{-1} respectively. NF soils showed the maximum soil microbial biomass carbon (SMBC) whereas the minimum was observed in BF with values ranging from 340 mg kg^{-1} to 345 mg kg^{-1}. Basal respiration was highest in RP (375 mg CO_2 m^{-2} hr^{-1}) and lowest in BF (224 mg CO_2 m^{-2} hr^{-1}). The findings demonstrated significant effect (p<0.05) of land use change on soil nutrient status and organic matter. Findings also indicated that land use change deteriorated native soil physicochemical and biological properties, but that land restoration practices through longer fallow period (>10 years) likely are successful in promoting the recovery of some soil characteristics.

Keywords: Land Use, Oil palm plantation, Organic matter, Rubber Plantation, Soil fertility

INTRODUCTION

Soil modification due to changes in land use types and patterns is a major threat to sustainable productivity of the soil (Ayoubi *et al.,* 2011) and is considered one of the major factors that affect the distribution patterns of nutrients (Islam and Weil, 2000) in the soil. Northeastern India is drastically affected by land use change (Grogan *et al.,* 2012; Tao *et al.,* 2018), particularly, shifting cultivation, closely linked to ecological, socio-economic, cultural and land tenure systems of tribal communities (Tripathi *et al.,* 2017) profoundly affects the soil fertility and crop productivity (Wapongnungsang *et al.,* 2018).

Mizoram, a region with steep slopes hills in Northeast India have undergone different land use change (Lallianthanga and Hmingthanpuii, 2013; Lallianthanga *et al.,* 2014) with more than 60% of the total population depending on small scale agricultural practices as it is the main source of livelihood for rural areas. The significant reduction in Jhum area is mainly due to the implementation of Oil Palm and Rubber plantation. Out of the total geographical area i.e., 2108700 hectare, the total potential area for Oil palm plantation was recorded as 101000 hectare. Rubber Plantation of about 1000 hectare is also established at different districts of the state (Economic survey Mizoram, 2016-2017). Bamboo forest covering 57 % of the total geographical area has shown a positive impact both in terms of forest cover and livelihood (MIRSAC, 2007).

SOC is an important component of the global carbon cycle indicating soil fertility and productivity (Van der Werf *et al.,* 2009) and studies have shown a significant variation with relation to land uses (Ali *et al.,* 2017; Iqbal *et al.,* 2014; Maurya *et al.,* 2014). The land use practices often influences the fluxes of soil carbon stocks and have been reported to vary with the change in land use systems. Various studies have reported a strong decrease of SOC after forest conversion to plantations (Guillaume *et al.,* 2015; van Straaten *et al.,* 2015). This has led to raise major concerns about the sustainability of such land use types in the tropics (Lal, 2010).

Although several studies have already been reported related to shifting agriculture (Hauchhum and Tripathi, 2017; Wapongnungsang, 2017; Wapongnungsang *et al.,* 2018), however, the impact of land use change and plantations on soil physicochemical and biological properties is poorly understood. Therefore, the present study aims to investigate the soil properties in five different land use systems, namely, Rubber Plantation, Oil Palm Plantation, Bamboo Forest, Fallow land (~20 yrs) and Natural Forest.

MATERIALS AND METHODS

Site description: Five different land use systems were selected from Mizoram, namely, Rubber Plantation (RP) (23°47.123' N lat and 92°36.831' E long), Oil Palm Plantation (OPP) (23°47.559' N lat and 92°36.492' E long) , Bamboo Forest (BF) (23°47.771' N lat and 92°36.080' E long), Fallow land (~20 yrs) (FL) (23°35.392' N lat and 92° 42.952' E long) and Natural Forest (NF) (23° 35.207' N lat and 92°43.016' E long). Three replicated plots (20m×25m) were established for each land use type to consider true site replicates by maintaining the minimum distance between plots with more than 15m (Mariotte *et al.*, 1997). All the studied land uses experiences moderate humid tropical climate (MIRSAC, 2007).

Soil sampling: Soils were collected from three replicated plots within each land use type following the simple random sampling technique. Soil auger was used to collect the soil samples from 10 different subplots within each replicated plots and further pooled as composite sample. Roots, stones, and debris if any, were removed and hand sieved through a 2 mm mesh sieve and separated into two parts. One part was air dried and the other part was kept in the deep freezer for further analysis.

Analysis of soil properties: Soil Bulk density (BD) was measured by collecting a known volume of soil using a metal ring pressed into the soil (intact core), and determining the weight after drying (McKenzie *et al.,* 2002). Soil texture was determined following the hydrometer method (Bouyoucos, 1962). The textural classification according to the United States Department of Agriculture (USDA) was followed to give the textural class of soil. Soil pH was measured in a soil-water suspension (1:2.5 soil-water ratios) with pH analyzer. The gravimetric method was followed to determine soil moisture content (SMC). Soil organic carbon (SOC) and total nitrogen (TN) was determined by dry combustion in a CHNS/O Elemental Analyzer with autos ampler and TCD detector –Euro Vector, Model: EuroEA3000. Ammonium nitrogen (NH_4^+-N) was estimated by Indophenol-blue method (Rowland, 1983) and Nitrate-nitrogen (NO_3^--N) by Phenol disulphonic acid method (Harper, 1924). Soil Microbial Biomass Carbon (SMBC) was determined by following the fumigation extraction method (Vance *et al.*, 1987). Oven-dry equivalent field-moist soil (25 g) was fumigated for 24 h at 25°C with ethanol-free $CHCl_3$. Following fumigant removal, the soil was treated with 100 ml of 0.5M K_2SO_4 by horizontal shaking for 1 h and then filtered. The other non fumigated 25 g soil was extracted simultaneously. MBC was calculated using k_{EC} factor of 0.38 (Vance *et al*., 1987). Soil basal respiration was estimated following the Alkali absorption method (AA-method) (Kirita, 1971).

RESULTS AND DISCUSSION

The studied soil physical properties were found significantly different across the land use systems (p <0.05) and the values are shown in Table 1. Bulk density (BD) values ranged from 1.06 g/cm^3 – 1.27 g/cm^3 with maximum density in RP which was followed by OPP>NF>FL>BF. The minimum bulk density in BF soils could be due to profuse root growth and dense root distribution in BF compared to other land uses. The conversion of the natural forest to plantations probably lead to loss of soil organic matter (SOM) that caused higher bulk density in the plantation soils. Higher bulk densities under intensive rubber plantation were previously reported in Indonesia (Allen *et al*., 2015; Guillaume *et al*., 2015). The soil texture of all the land use was determined to be sandy loam with sand, silt and clay values ranging from 62.5% - 71.2%, 17.0% - 20.6% and 11.8% - 16.9% respectively. High sand percent was estimated from BF soils and clay percent was high in plantation soils compared to other land uses.

The soils were found to be acidic in nature with a narrow pH range among the land use systems. Soil pH and moisture content values ranged from 3.9 to 4.9 and 17.4% to 23.4% respectively (Table 1). The NF soil was highly acidic compared to RP, BF, OPP and FL. Similarly, the moisture content was also higher in NF soils. High organic matter content and dense vegetation in NF probably conserve the soil moisture. It has been reported that forest conversion to plantations in Indonesia, Peru and Southern Cameroon led to low moisture availability due to losses in the top soil and vegetation (van Straaten *et al.,* 2015; Guillaume *et al.,* 2016).

The values of SOC and TN were found higher in NF followed by FL, BF, OPP and RP (Table 1) and the values ranged from 2.02% to 2.81% and 0.22% to 0.3% respectively. High SOC in NF can be accounted by a considerable amount of litter decomposition and availability of soil nutrients. The higher inputs of organic matter and nutrients

Table 1. Soil properties of different land use systems. Values are mean±1SE (n=5). LSD is shown at *p<0.05.*

SOIL VARIABLES	LAND USE SYSTEMS					
	Rubber Plantation	**Bamboo Forest**	**Oil Palm Plantation**	**Fallow Land**	**Natural Forest**	**LSD**
Bulk Density	1.27 ±0.04	1.06 ±0.01	1.16 ±0.02	1.09 ±0.01	1.10 ±0.004	0.18
Sand (%)	62.5 ±0.10	71.2 ±0.99	63.7 ±2.08	68.6 ± 0.05	69.2 ±1.91	4.23
Silt (%)	20.6 ±0.04	17.0 ±0.94	19.6 ±1.63	17.8 ±0.55	18.8 ±0.78	2.97
Clay (%)	16.9 ±0.05	11.8 ± 1.94	16.7 ±0.45	13.6 ±0.6	12.0 ±1.13	3.34
Soil pH	4.68 ±0.05	4.91 ±0.08	4.65 ±0.14	4.84 ±0.07	3.93 ±0.12	0.31
Soil Moisture (%)	20.3 ±0.7	21.3 ±1.0	17.4 ±1.14	22.3 ±0.6	23.4 ±0.11	2.88
Soil Carbon (%)	2.02 ±0.15	2.32 ±0.05	2.22 ±0.14	2.36 ±0.15	2.81 ±0.1	0.38
Total Nitrogen (%)	0.22 ±0.01	0.23 ±0.01	0.23 ±0.007	0.26 ±0.008	0.3 ±0.11	0.06
Ammonium (mg/kg)	7.34 ±0.88	10.2 ±1.5	7.58 ±1.3	5.60 ±0.46	8.96 ±0.8	3.14
Nitrate (mg/kg)	1.25 ±0.36	1.94 ±0.5	2.81 ±0.14	1.15 ±0.13	2.81 ±0.3	1.03
Soil Microbial Biomass Carbon (mg/kg)	341.9 ±10.31	340 ±12.3	341.2 ±12.3	343.4 ±3.6	345.2 ±15.0	31.8
Soil Respiration ($mgCO_2/m^2/hr$)	375 ±39.5	224.1 ±42.8	372.9 ±30.2	345.2 ±31.3	345.4 ± 35.7	106

through litter fall have positively shown to affect soil organic matter (Hattori *et al.,* 2005; Ouyang *et al.,* 2007). SOC availability is a good indicator of soil nutrient supply in tropical ecosystems (Chen *et al.,* 2010). It has been reported that soil erosion is the factor affecting the SOC loss in oil palm plantations of Peninsular Malaysia (Gharibreza *et al.,* 2013). In contrast to other land use, less SOC in OPP may be due to the effect of land management activities under plantation. The regular clearance of the surface through weeding and removal of the fallen leaves leads to low microbial activity.

Available forms of nitrogen play an important role in N transformation. The values of NH_4^+-N and NO_3^--N ranged from 5.6 mg kg^{-1} to 10.2 mg kg^{-1} and 1.15 mg kg^{-1} to 2.81 mg kg^{-1} respectively. Higher range of NH_4^+-N and NO_3^--N in NF soils depicted higher rate of ammonification and nitrification which were favoured by high soil moisture content in NF. Results suggested that soil moisture stimulated the soil microbial activity, as also observed in natural and regenerated tropical forests soils of Brazil (Silva *et al.,* 2012).

The values of soil microbial biomass carbon (SMBC) in the land use types ranged from 340 mg kg^{-1} to 345 mg kg^{-1}. NF soils exhibited the maximum SMBC whereas the minimum was observed in BF. Several workers have found a close relationship between soil moisture and microbial biomass (Devi and Yadava, 2006; Singh *et al.,* 2010). Results showed that SMBC were greatly influenced by SOC. Several reports (Chen *et al.,* 2005; Chen *et al.,* 2017) have shown that higher SOC enhances the growth of microbes and causes accumulation of microbial biomass in soil.

The change in soil respiration rates due to soil temperature and moisture under climate change often contributes to the responses of soil respiration in different ecosystems. Basal respiration in BF was significantly different (*p*<0.05) compared to other land uses with highest in RP followed by OPP>NF>FL and lowest in BF. The values ranged from 224 to 375 mg CO_2 m^{-2} hr^{-1} (Table 1). The greater soil microbial activity in RP, OPP and NF could release more nutrients from soil organic matter for fine root uptake which further lead to increase in soil respiration compared to FL and BF. Guntinas *et al.* (2013) reported that higher moisture content in the soils of forest, grassland and cropland is responsible for higher soil respiration rate. Low SMBC and basal respiration in BF indicates the proliferation of profuse root systems in BF as to exploit soil nutrients from the greater volume of soil to compensate high productivity of BF.

Conclusion

This study highlights the soil properties of different land use types of Mizoram. Results showed a distinct change in soil properties with the land use change ultimately leading to negative feedbacks between soil property and land use types. It further indicated that land use change to RP and OPP deteriorated native soil physicochemical and biological properties, but land restoration practices through longer fallow period (>10 years) are likely to promote the recovery of inherent soil characteristics. However, a long term observation of the land use change is recommended for further study to follow in order to understand the chrono sequence effect of land use change.

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