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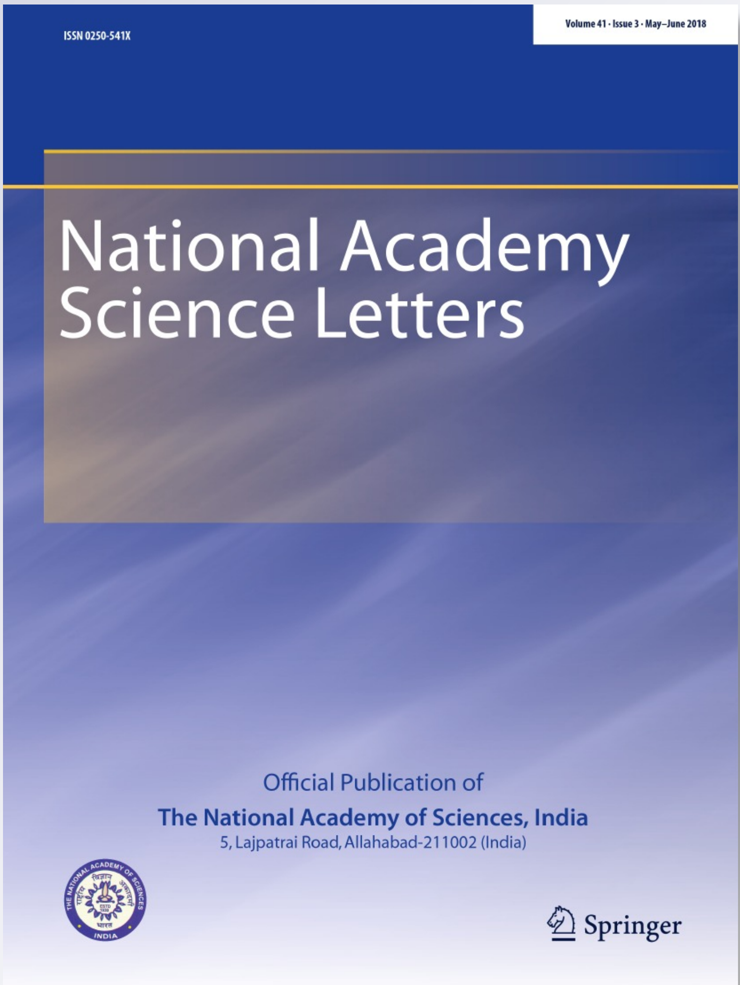

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SHORT COMMUNICATION

Effects of Land-use on Soil Physical, Chemical and Microbial Properties in Humid Subtropical Northeastern India

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Abstract A study was conducted to examine the impact of land-use on soil properties in humid subtropical India. Soil samples were collected from two depths 0–20 cm (surface layer) and 20–40 cm (sub-surface layer) of soil from four land-uses (viz. natural forest, tea plantation, horticultural system and agriculture) located on varying slopes and examined for particle size distribution, pH, organic carbon (OC), exchangeable cations (Ca, Mg, Na and K), microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN). There were significant difference in sand, silt and clay with land-uses in the surface and sub-surface layers except the clay fraction in the sub-surface layer in all the land-uses. OC (2.17%) was greatest in forest soil, followed by soil from horticultural system, tea plantation and agriculture. The greatest Ca (3.8 cmol/kg) and K (0.7 cmol/kg) were found in the forest, whereas Mg (1.5 cmol/kg) was greatest in horticultural system. The MBC and MBN in the surface layer were highest (237.6 and 80.4 mg/kg, respectively) in the forest and lowest (135.0 and 46.8 mg/kg, respectively) in the agriculture, which was subjected to intense human activities. OC, MBC and MBN declined with increasing soil depth in all the land-uses.

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With the rapid increase of population and limited land resources, many countries throughout the world are facing acute scarcity of lands for food production, which causes people to convert forestland into agricultural, horticultural, and many other kinds of land. The destruction of the natural forest and its conversion to cropland can reduce soil productivity because of increased erosion, cause decline in fertility and microbial properties, which plays a crucial role in sustaining soil and environmental quality [1].

Soil health has been defined as the capacity of a soil to support ecosystem functions and sustain biological productivity and environmental quality [2]. Poor soil management and the replacement of native forests by farmland may compromise soil health. Because several chemical, physical and biological properties are used to characterize soil health, identifying the most sensitive of these is useful for assessing the impacts of land-use change. Levels of soil organic carbon, generally considered an indicator of soil health [3], depend on inputs of plant litter and rhizodeposition [4, 5]. Changes in a site's original vegetation or improper soil use may impair C cycling, decrease soil organic matter content, and increase CO_2 emissions [5, 6], thereby contributing to the greenhouse effect.

The soil microbial biomass acts as a labile reservoir of plant available nutrients [7]. It constitutes a significant part of the potentially mineralizable-N and plays an important role in N cycling due to rapid turnover rate. Garcìa-Gil et al. [8] concluded that microbial biomass is a much more sensitive indicator of changing soil conditions than the total organic matter content. In recent years, studies on microbial biomass and their activity have engaged the attention of many researchers for understanding early changes in biological quality of soil following changes in the land management [9, 10]. However, most of these studies are confined to agricultural soils and such studies are rather limited in forest ecosystem. Keeping these facts in mind, the present study was undertaken to compare the influences of four most common land-uses on selected soil physical, chemical and microbial properties in humid subtropical Northeastern India.

The study was carried out in Junglegaon, Titabar Block, Jorhat district, Assam, extending between 26°35′26″–26°36′36″N latitudes and 94°18′58″–94°20′22″E longitudes covering an area of 781 ha. The climate of the area is humid subtropical. The mean winter and summer air temperatures are 17.0 and 28.7 °C respectively. Annual rainfall is 2250 mm. Geologically the area is formed from sediment derived from the Assam plateau carried by Brahmaputra river and its tributaries. According to the USDA Soil Taxonomy, the soil at the study region was classified into two orders viz. Entisols and Inceptisols. The native forest in the study area is dominated by Ajhar (*Lagerstroemia flosreginae*), Bot (*Ficus bengalensis*), Boga Koroi (*Alvizzia procer*), Khokon (*Duabanga sonnertioides*), Nahar (*Mesua ferrea*), Outenga (*Dillenia indica*), Sonari (*Cassia fistula*), Sisoo (*Dalbergia sisoo*), Simolu (*Bombax malabaricum*) and Bamboo (*Bambusa* sp.) etc.

Soil sampling sites were selected within four major land-uses located on varying slopes since native forests were clear cut 40–50 years ago. The slope gradient was found to be between 0–3% in the lower, 3–8% in the middle and 8–15% in the upper units dominated by cultivated land, horticultural practices, and native forest and tea plantation, respectively. A total of 160 soil samples (20 locations × 4 land-use systems × 2 depths) were collected from major land-use system of native forest, tea plantation, horticultural practices and cultivated land. Soil pH was determined in 1:2.5 soil/solution ratio. Particle size distribution was determined by the hydrometer method and moisture content gravimetrically. Organic carbon (OC) was determined by Walkley and Black [11] method. Total Kjeldahl nitrogen (TN) was determined by using Kjeltec Kel Plus-Supra LX (VA). Exchangeable cations (Ca, K, Mg and Na) were extracted with 1 M NH_4OAc (pH 7.0). K and Na contents were determined by flame photometer, while the Ca and Mg were determined by EDTA titration method. Microbial biomass carbon (MBC) determinations were made by using chloroform fumigation technique as described by Jenkinson and Powlson [12] and Jenkinson and Ladd [7]. Microbial biomass nitrogen (MBN) determination was made by using the standard method [13]. All the statistical analyses were performed using SPSS v.17.0. One-way analysis of variance was performed to test the effect of land-uses on each soil properties. Turkey's HSD (honest significance difference) test was used for mean separation when the analysis of variance showed statistically significant difference ($p < 0.05$) between the soil properties.

The clay fraction was invariably lower compared to sand and silt in all the land-use systems (Fig. 1). There were significant difference in sand, silt and clay with land-uses at surface layer (0–20 cm depth) and sub-surface layer (20–40 cm depth), except the clay fraction between the land-uses in the surface layer were non-significant. Sand content (54.2%) in the surface layer in tea plantation (upper slope), silt content (44.8%) in surface layer in horticultural practices (middle slope) and clay content (38.6%) in the sub-surface layer in horticultural practices were highest as compared to other land-uses. The results were in accord to the trend in soil texture over landscape for increased fine particles on lower slopes [14]. Furthermore, the much significant difference in silt but not clay content between middle and lower slope indicated non-selective removal of the clay particles from the soil surface and transported to the lower slope position. Steeper slopes contribute to greater runoff, as well as to greater translocation of surface materials downslope through surface erosion and movement of the soil mass. The soil moisture content of soil ranged from 33.2% in the sub-surface soil layer of horticultural practices to 40.9% in the surface soil layer of agriculture. However, it did not vary significantly between the sub-surface layers of all the land-uses.

Soil pH showed significant influence of land-uses (Table 1). The soil was acidic in all land-uses with pH ranging between 4.9 in horticultural systems to 5.7 in natural forest. The forest showed greater pH than the arable land, which could be attributed to the release of bases and their deposition over a long period of tree growth. The acidic nature of cultivated soil could also be attributed to acidification through several processes. Earlier results also revealed that trees have the capacity to moderate the effects of leaching by contributing bases to the soil [15, 16]. Among the exchangeable cations, Ca and Mg were the most dominant, followed by Na and K. Among all the exchangeable cations only Ca showed a significant difference with land-uses. The difference in exchangeable bases in different land-uses was due to difference in slope positions which is one of the most important abiotic factors that control the pedogenic process on a local scale [17], and affects the movement and accumulation of soil solution leading to variation in exchangeable bases. There was inconsistent variation of exchangeable Mg, K and Na with respect to land-uses. Similar results had also been reported by Reza et al. [18].

The OC content was greater in forest (2.17%) followed by horticultural system (2.06%). The least value for OC (0.69%) was found in sub-surface layer for agriculture

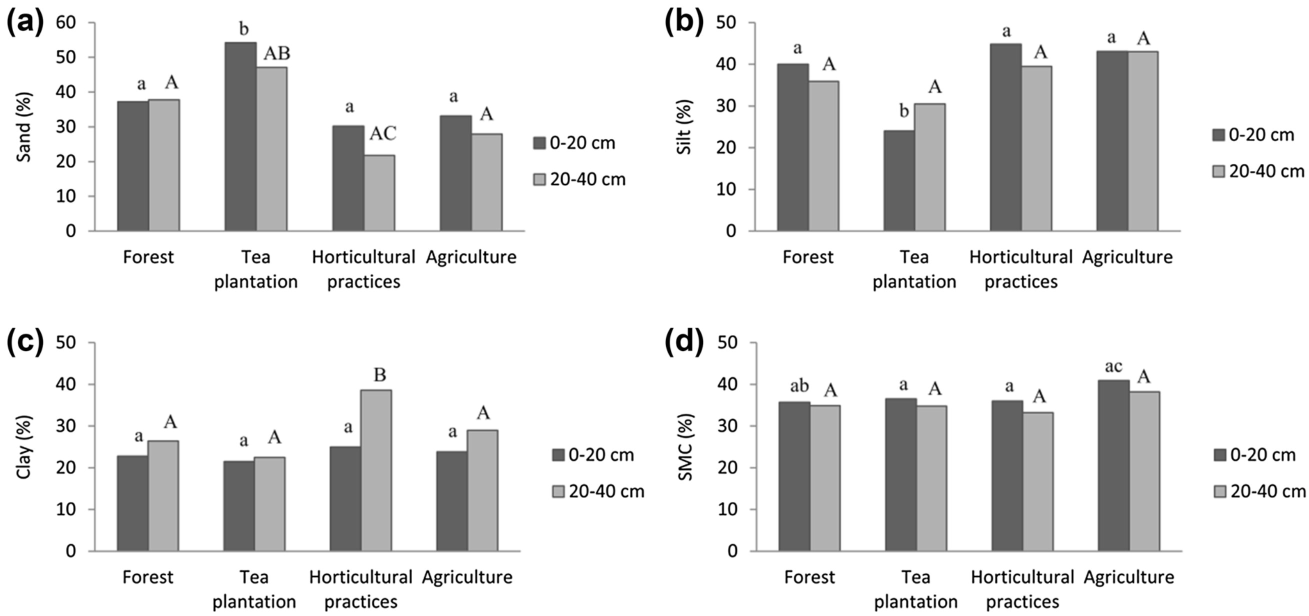

Fig. 1 **a** sand, **b** silt, **c** clay and **d** soil moisture content in soil under different land uses. Mean sharing the same lower case and upper case letter are not statistically different at 0–20 and 20–40 cm depth, respectively

Table 1 Soil chemical properties (0–25 and 25–50 cm depths) in relation to land uses

Parameters	Depth (cm)	Land use			
		Forest	Tea plantation	Horticultural practices	Agriculture
pH	0–20	5.2^{a}	5.0^{a}	4.9^{ab}	5.7^{ac}
	20–40	5.3^{a}	4.9^{b}	4.9^{b}	5.7^{a}
Exchangeable Ca (cmol/kg)	0–20	3.8^{a}	3.8^{a}	2.5^{b}	2.7^{b}
	20–40	1.7^{a}	2.8^{b}	1.5^{a}	1.7^{a}
Exchangeable Mg (cmol/kg)	0–20	1.5^{a}	1.2^{a}	1.5^{a}	1.3^{a}
	20–40	0.7^{a}	0.9^{a}	0.9^{a}	0.9^{a}
Exchangeable K (cmol/kg)	0–20	0.2^{a}	0.1^{a}	0.2^{a}	0.2^{a}
	20–40	0.7^{a}	0.4^{a}	0.5^{a}	0.3^{a}
Exchangeable Na (cmol/kg)	0–20	0.3^{a}	0.2^{a}	0.4^{a}	0.3^{a}
	20–40	0.2^{a}	0.2^{a}	0.4^{a}	0.5^{a}

Means within a row followed by a different letter are significantly different according to LSD 0.05

(Fig. 2). The surface layer tended to be richer in OC than subsoil layers in all land-uses. This may be attributed to the contribution made by litter fall [15]. Jha et al. [19] and Reza et al. [16] had also reported that soils under horticulture and forest systems showed greater amounts of soil OC than agriculture lands. The MBC and MBN varied significantly among the land-uses at different soil depths (Fig. 2). The MBC and MBN were greatest under surface soil of forest (237.6 and 280.4 mg/kg, respectively) and least in the sub-surface soil layer under agriculture (52.6 and 18.2 mg/kg, respectively). The chief contributory factor for the higher MBC and MBN in the forest soil than the agriculture seems to be the greater availability of organic nutrients in the forest due to higher plant covers [16]. Min et al. [20] also reported that the addition of organic matter and better nutrient cycling in forest in upper slope position might have increased the biological activity of the soil.

Land-uses and slope position affected soil properties further leads to variation in soil microbial properties. It is evident from the study that forest soil having higher OC content, exchangeable cations and microbial activities over the arable land. Further, human activities such as agricultural and horticultural practices in the study area with high

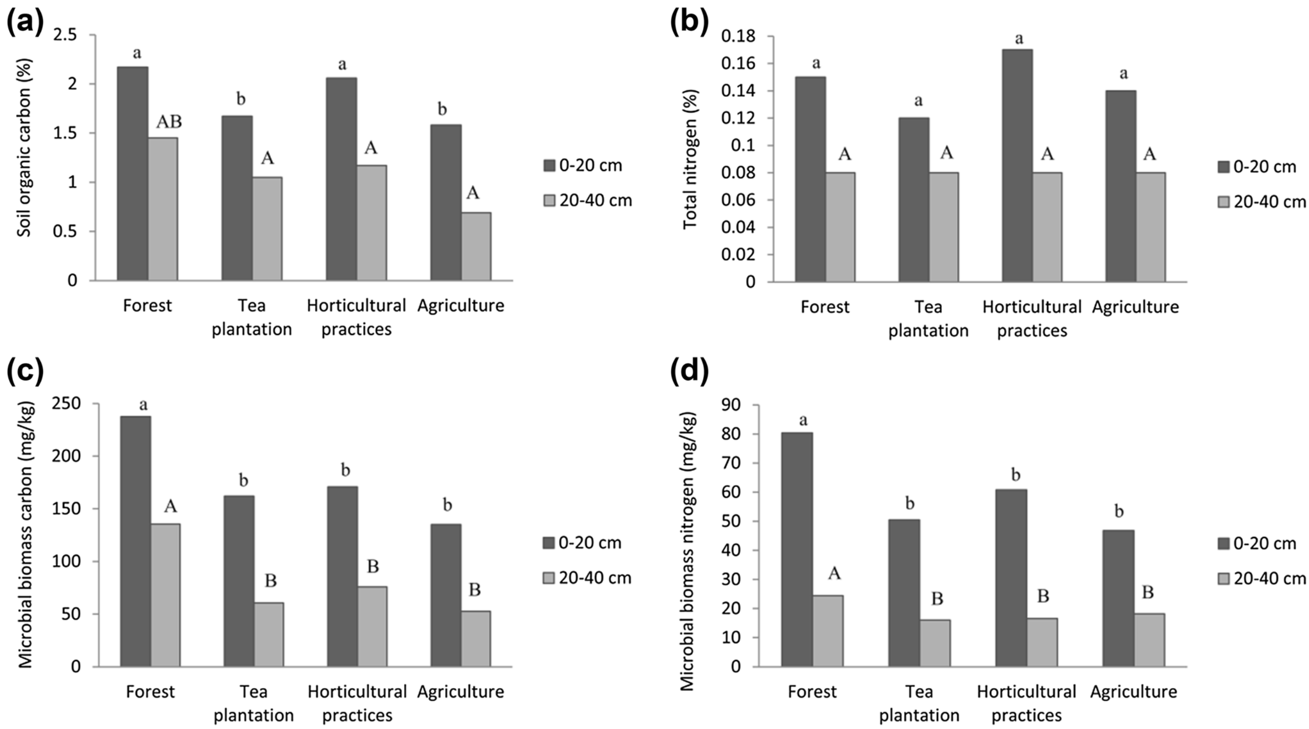

Fig. 2 **a** soil organic carbon, **b** total nitrogen, **c** microbial biomass carbon and **d** microbial biomass nitrogen in soil under different land uses. Mean sharing the same lower case and upper case letter are not statistically different at 0–20 and 20–40 cm depth, respectively

rainfall and light texture soil causes depletion of the MBC and MBN. We infer from the study that forests have better soil quality than other tree-based land-use systems.

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