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Influence of land use type on different aggregating elements of acidic soil of Meghalaya, India

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Abstract
Inappropriate land use system in Meghalaya aggravates to soil erosion and other soil degradation. The land use is an important factor affecting soil organic carbon (SOC) accumulation and storage in soils. The study was conducted at Bhoirymbong of Ri-Bhoi District, Meghalaya in eight (8) different land use systems *viz. Jhum,* Upland Rice, Terrace Rice, Rice mono-culture, Rice-Potato, Pineapple, Mixed forest and Broom grass. The soil texture, soil organic carbon (SOC), soil microbial biomass carbon (SMBC), Exchangeable Ca+Mg and hot water extractable carbon (HWEC) were measured in soil of different land uses. Aggregates were fractionated using a wet-sieving procedure to obtain the distribution of water-stable aggregates. Mean Weight Diameter (MWD) is found highest in Upland Rice (2 mm) and Terrace Rice (1.72 mm) at 0-10 cm and 10-20 cm depth, respectively in the study area. Furthermore, higher MWD in surface soil was obtained from Upland rice which indicated that as the Upland rice cultivation is traditionally a mono-culture activity without much soil manipulation the aggregation might not have broken in the cultivation process. The pH is moderately acidic in nature ranging in Bhoirymbong (5.26-6.42). Clay content was highest in Pineapple system (0-10cm) and Terrace Rice system (10-20cm) in Bhoirymbong area. In case of MWD, it was the highest in Upland Rice (2 mm) and Terrace Rice (1.72 mm) at 0-10 cm and 10-20 cm depth, respectively in both the study areas. At both depth of Bhoirymbong areas, Exch. Ca^{++} and Mg^{++} was found to be highest in Rice monoculture system (3.32 meq/100g soil and 2.68 meq/100g soil). SMBC, Exchangeable Ca^{++} and Mg^{++}, Clay, HWEC and SOC show significant ($p \leq 0.05$) and strong positive correlation with MWD at both depths. The findings from this study had shown the land use system had significant influence on the aggregating elements. Besides, the influence of land use system on aggregating elements varied according to land uses. Hence, the findings of this study clearly shown that the proper selection of land use according to the state of soil aggregating elements for better soil sustainability.

Keywords: Soil aggregation, microbial biomass carbon, soil organic carbon, hot water extractable carbon

Introduction

Soil is an integral part to study for sustaining better soil health as the crop productivity depends on it. Soil aggregation is a clustering of soil particles which occurs naturally and the forces holding the particles together are much stronger than the forces between adjacent aggregates (Martin *et al*., 1955) [15]. Aggregate formation increases moisture-holding capacity of soil and reduces erosion. It also maintains sufficient cohesion in the soil to give anchorage to plant, yet sufficient incoherence to facilitate root penetration and emergence of seedlings. It is a well-known fact that with the variation of the size of aggregates, the binding agents are different and also size of aggregation varies according to different land use type. The land use is an important factor affecting soil organic carbon (SOC) accumulation and storage in soils, which controls the magnitude of SOC stock and also greatly influences the composition and quality of organic matter in soils (Six *et al*., 2002; John *et al*., 2005; Helfrich *et al*., 2006) [24, 12, 9]. The SOC and aggregates mutually protect each other, since SOC is physically protected by its association with soil primary particles in aggregates; at the same time, aggregate stability is enhanced by this association (Six *et al*., 1999, 2000, 2002) [25, 26, 24]. Six *et al*. (2000) [26] reported that cultivation reduced soil organic carbon (SOC) content and changed the distribution and stability of soil aggregates. The highest total organic C, total polysaccharides and dilute acid extracted polysaccharides contents were found in 2.00-1.00 mm water-stable aggregates and the lowest contents were found in <0.25 mm aggregates (Acton *et al*., 1962) [1]. In hilly regions, erosional processes are enhanced after land use change and affect the soil properties considerably (Afshar *et al*., 2010) [2]. Soil susceptibility to erosion is closely related to the top soil aggregate stability (Barthès *et al*., 1999) [3].

Erosion is in fact expected to impede the development of soil structure (Poch and Antunez, 2010) [20] as aggregates can build up only when losses of finer particles and cementing agents are limited (Shi *et al*., 2010) [29] and, consequently, when erosion is not too intense. So, it is required to reduce the degree of disturbance in soil physical disturbances by adopting suitable farming systems so as to manage the soil carbon in the agricultural lands. A better understanding on the relationship among the landscape, land use, soil texture and soil aggregation will help the agriculture scientists to plan the sustainable landscape management and protect the already fragile land eco-system. Therefore, an attempt has been made in this study to determine the effect of land use type on soil aggregating elements.

Materials and Methods

Four random spots were considered with each land use system (Fig. 1) from the study site. The soil samples were collected from random spots and pooled together to make one composite per random location. Soil samples were collected at two different depths (0-10 cm and 10-20 cm). Thus, 4 composite soil samples from each soil depth were collected for each land use type. Approximate 700 g soil per composite sample were collected and one part of the soil sample (approx. 100 g) were immediately stored at 4^0C in the laboratory for soil biochemical analyses. Other part of the soil samples (approx. 700 g) were air-dried and around 200g of the air-dried sample were kept for soil aggregation analysis and the remaining soil (approx. 500g) were ground and passed through 1 mm sieve and stored for further analysis. Soil samples were analysed for some important physico-biochemical properties following the standard protocol. The pH of the soils was determined by using soil-water suspension (1:2.5) following the method of Page *et al.* (1982) [18]; Soil Organic Carbon (SOC) by Walkley and Black (1934) [30]; Soil Microbial Biomass Carbon by Brookes and Joergensen (2006); Exchangeable Ca^{++} and Mg^{++} by Page *et al.* (1992) [17]; Soil Texture by Piper (1966) [19], Hot Water Exchangeable Carbon by Ghani *et al.* (2003).

Statistical Analysis

Univariate statistics were performed using SPSS v12.0 (Statistical Packages for Social Science Inc., Chicago, IL, USA). Means were tested at a significant level of $P \leq 0.05$ using Tukey's HSD test for multiple pair-wise comparisons among means.

Results and Discussion

pH

The pH of soil of the experimental site varied between 5.26-6.42 (Table 1). The soil pH decrease with the increase in depth except in case of Pineapple cultivation and Rice-Potato system and Rice monoculture system. The relative decline in soil pH at the soil surface of the soils under the mixed forest land could be due to oblong shaped canopy leading the rain to form big drops consequently enhancing leaching of basic cations as well by releasing organic acids associated with mineralization of organic matter (Mohammed *et al*., 2005) [16]. Soil pH increased consistently with depth in all land use systems. This pattern of variability in soil pH suggested the increase in bases with increase in depth that could be attributed to the downward movement of solutes by leaching within a profile (Mohammed *et al*., 2005) [16]. Malo *et al.* (2005) [14] also reported that the increase in pH with soil depth could be associated with enhanced carbonate levels and less weathering rates.

Soil Organic Carbon (SOC)

SOC was found to be highest in surface soil of Terrace Rice system and in case *Jhum* system in sub-surface layer which was followed by Mixed Forest and Pineapple systems (Table 2). The lowest SOC content was found in Rice-Potato system. SOC significantly affected the MWD under different land use system. Shrestha *et al.* (2007) [28] reported the higher variability in SOC concentration under cultivated soils, whereas, the variability narrowed down in the micro-aggregates this also implies that losses of C from macro-aggregates are usually more rapid than those from micro-aggregates due to a lower protective effect of biophysical and chemical processes (Jastrow and Miller, 1997) [11]. There is considerable concern that land use change could alter soil carbon (C) (Houghton, 1999) [10] and nitrogen (N) (Potter *et al*., 1996) [21] cycle.

Soil Microbial Biomass Carbon (SMBC)

The microbial biomass carbon (MBC) as one of the labile soil carbon fractions has been proposed as an important indicator of changes in soil management practices (Culman *et al.*, 2012) [5]. The concentration of SMBC in Upland Rice followed by Mixed Forest system obtained highest at surface soil and at the subsurface soil, Upland rice obtained highest in the study site (Table 2). In most of the studies referred, the forest land has considerably higher amount of SMBC than other agricultural land which shows the higher microbial activity (Wright *et al.*, 2005, Feng *et al.*, 2009, Pramod *et al.*, 2012) [31, 6, 22]. The lower MBC content in soils under agriculture land than in other land uses can be explained by rapid oxidation of organic carbon through exposure of the organic matter to microbial attack, as was also reported by Sharma *et al* (2014) [27].

Exchangeable Ca and Mg

At both depth of Bhoirymbong areas, it was found to be highest in Rice monoculture system followed by Terrace Rice system and the least in Broom grass system. The presence of higher amount of exchangeable Ca and Mg, which shows significant relationship with the MWD influencing in the higher stability of the aggregate. Table 1 and 2 shown that the land use system where the pH was moderately high, the Exchangeable Ca and Mg content was also relatively high which can be correlated that the higher content of the exchangeable cations led to the increase in soil pH.

Soil Texture

Soil texture varies with land use system. The textural class are defined using the USDA triangular textural diagram (Fig 2). The clay content of the surface soil was highest in the Pineapple (43.3%) and for subsurface soil, in Rice monoculture (46.3%) has the highest content. Lawal *et al*. (2009) also observed that changes in land use practices influenced MWD and all aggregate fractions (except for silt + clay fraction). The clay fraction influenced in the aggregation of soil (Table 1).

Hot Water Exchangeable Carbon

The availability of the organic carbon fractions is higher at the surface soil as the microbial activity is high. HWEC content decreases with increase in depth except in Terrace Rice system which significantly affected the stability of the soil (MWD) under different land use system Table 2). The highest HWEC at the surface soil obtained in Upland Rice (101.4 µg C/g soil) and at the subsurface soil, the highest HWEC was obtained in Terrace Rice (142 μg C/g soil) system. Haynes and Swift (1990) and Haynes *et al*. (1991) similarly found that hot water-soluble carbohydrates were best correlated with aggregate stability as compared to other fractions in pasture soils. This finding could be referred to the higher content of HWEC in the Upland Rice condition and obtained the highest MWD content in the same land use system. The loss of organic carbon with cultivation could be attributed to the repeated exposure and subsequent aeration and oxidation of light fraction of organic carbon associated with macro-aggregates and macro-pores (Shephered *et al*., 2001). A decline in HWEC with cultivation is consistent with a decline in soil structure, which suggest that, this fraction is involved in aggregate formation through physical binding and chemical cementation.

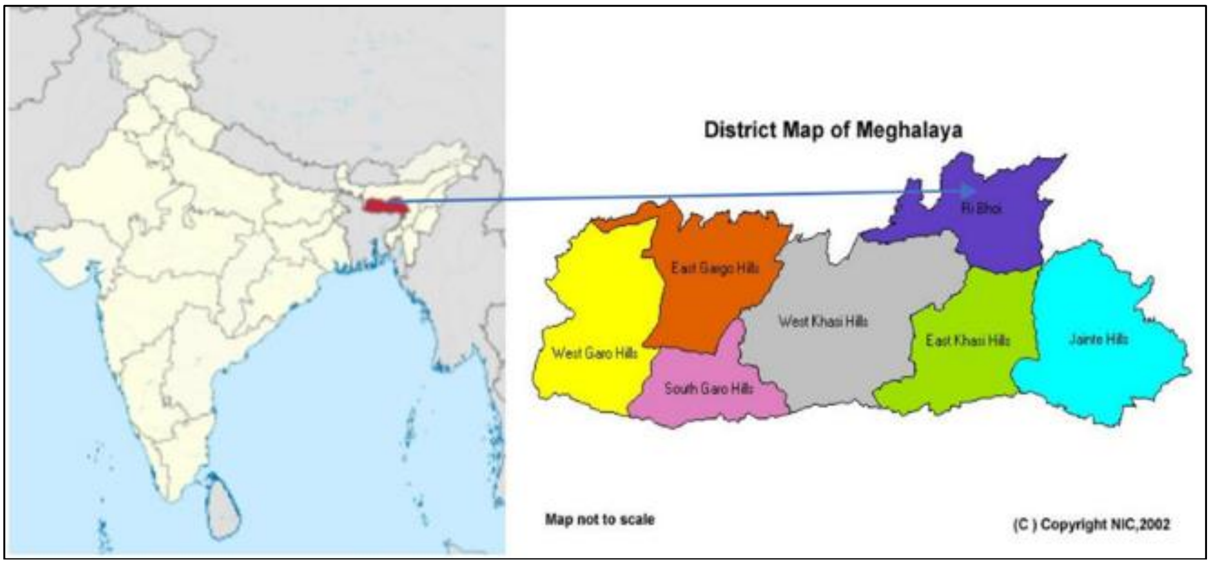

Fig 1: Location map of study area

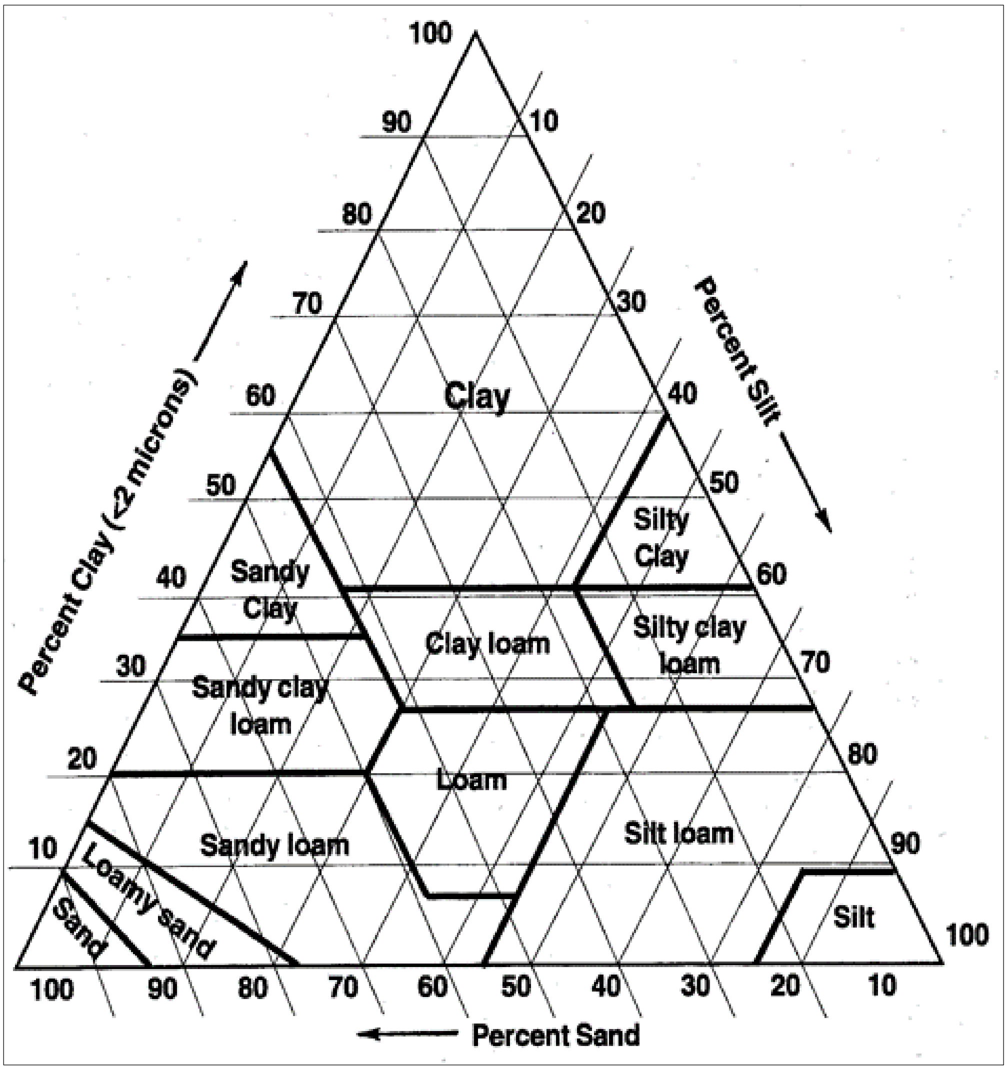

Fig 2: USDA Triangular textural diagram

Table 1: The soil physical properties for Bhoirymbong site at 0-10 cm and 10-20 cm depth

Land Use	**MWD (mm)**		**Texture**			**Texture**		
	0-10	**10-20**	**0-10**			**10-20**		
			Sand (%)	**Silt (%)**	**Clay (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**
Jhum	1.26±0.003b	1.27±0.01c	39.8±2.90c	34.4±2.06bc	25.8±1.28a	37.0±0.71e	34.5±1.08a	28.5±0.58a
Pineapple	1.52±0.01d	1.37±0.01d	32.6±1.98abc	24.1±2.77a	43.3±2.67e	31.5±0.74cd	30.1±3.05a	38.4±2.66bc
Rice monoculture	1.40±0.04c	1.47±0.01e	27.8±2.07a	31.6±1.30abc	40.6±2.53cd	27.8±1.38bc	30.5±3.52a	41.7±3.22c
Terrace Rice	1.51±0.02d	1.72±0.02g	27.0±1.67a	39.4±0.83c	33.6±0.88abc	23.2±0.63ab	30.5±2.13a	46.3±1.56c
Upland Rice	2.00±0.02f	1.64±0.01f	27.4±1.28a	32.1±1.25abc	40.5±0.35cd	20.3±1.94a	34.6±3.10a	45.1±2.25c
Rice-Potato	1.04±0.01a	0.89±0.01a	31.3±1.66ab	36.3±1.61c	32.4±1.51abc	34.5±1.59de	34.5±0.87a	31.0±1.54ab
Mixed Forest	1.86±0.02e	1.47±0.01e	36.4±0.31bc	27.1±2.06ab	36.5±2.03bcd	30.4±1.64cd	37.8±1.39a	31.8±0.48ab
Broom Grass	1.21±0.02b	1.15±0.04b	31.1±0.88ab	38.8±2.89c	30.1±2.13ab	33.6±0.43de	38.1±1.21a	28.3±1.16a

Mean ± SE; Within a column (parameter) values followed by different letters are statistically significant as determined by one-way ANOVA incorporating Tukey's HSD test for multiple pair-wise comparisons among means. [MWD; Mean Weight diameter]

Table 2: The pH, Exch. Ca+Mg, SOC and SMBC for Bhoirymbong site at 0-10 cm and 10-20 cm depth

Land Use	**pH**		**Exch.Ca^{++}+Mg^{++} (meq/100g soil)**		**SOC (%)**		**SMBC (µg C/g soil)**		**HWEC (µg C/g soil)**	
	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20
Jhum	5.71±0.004d	5.33±0.003b	1.22±0.06a	1.00±0.05a	2.23±0.01c	2.16±0.02f	558±3.84e	395±15.1b	77.4±0.70b	76.9±0.26bc
Pineapple	5.54±0.01c	5.65±0.01d	2.93±0.15c	2.39±0.20cd	2.71±0.02f	2.01±0.03e	686±.00f	455±18.6c	101.4±0.45e	81.3±0.31de
Rice monoculture	6.42±0.001g	6.22±0.004f	3.32±0.11c	2.68±0.09d	2.03±0.02b	2.15±0.01f	306±2.51a	689±10.3e	85.5±1.29d	84.1±0.32e
Terrace Rice	5.76±0.004f	5.43±0.01c	3.28±0.13c	2.43±0.15cd	2.73±0.01f	1.47±0.02b	340±4.44b	986±5.5g	74.0±1.19a	142±2.24f
Upland Rice	5.43±0.004b	5.33±0.01b	3.13±0.06c	2.47±0.10cd	2.32±0.02d	1.86±0.02d	843±2.51h	674±4.23e	145±0.96f	84.5±0.13e
Rice-Potato	5.72±0.01de	5.88±0.004e	2.37±0.10b	1.57±0.09b	1.44±0.02a	1.18±0.02a	492±8.02d	290±25.7a	81.3±0.21c	72.1±0.42a
Mixed Forest	5.37±0.01a	5.32±0.01b	2.99±0.04c	2.01±0.09c	2.48±0.02e	1.61±0.01c	752±3.70g	746±5.11f	99.4±0.13e	79.2±0.17cd
Broom Grass	5.74±0.004ef	5.26±0.01a	1.02±0.05a	0.68±0.03a	1.47±0.01a	1.20±0.01a	401±0.89c	542±9.68d	75.5±0.50ab	74.4±0.47ab

Mean ± SE; Within a column (parameter) values followed by different letters are statistically significant as determined by one-way ANOVA incorporating Tukey's HSD test for multiple pair-wise comparisons among means [SOC; Soil Organic Carbon, SMBC; Soil Microbial Biomass Carbon, HWEC; Hot Water Extractable Carbon]

Conclusions

The result therefore reveals that among the different land use system had significant influence on aggregating elements. Hence, the findings of this study clearly traced upon the proper selection of land use according to the state of soil aggregating elements for better soil sustainability.

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