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Variability of soil properties in Sikhe village under Lower Subansiri district, Arunachal Pradesh

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ABSTRACT

*The study was conducted under three land uses, viz., terrace, jhum and forest to assess the variability of soil properties in Sikhe village under Lower Subansiri district, Arunachal Pradesh. The soil pH was strong to moderate acidic in reaction (pH 4.6 to 6.1). Organic carbon ranged from 10.7 to 46.0 g kg^{-1} which was found to be highest in forest ecosystem among the land uses. Cation exchange capacity (CEC) ranged between 7.9 and 22.8 cmol (p^{+}) kg^{-1} and had significant positive correlation with organic carbon (r=0.68**). Bulk density varied from 1.10 to 1.56 Mg m^{-3}, and showed significant negative correlation with organic carbon(r= -0.61*). Bulk density of forest was recorded to be the lowest. Water holding capacity (WHC) varied from 37.0 to 64.2 %, and was found higher under forest land use. WHC had significant positive correlation with organic carbon (r=0.55*) and significant negative one with sand (r=-0.62*). Hydraulic conductivity varied from 0.21 to 1.86 cm hr^{-1}, and was found lowest under terrace land uses. Water stable aggregates (WSA > 0.25) ranged from 83.0 to 96.8 %. Mean weight diameter of the soil varied from 0.52 to 0.88 mm. The textural classes of various soils under different land use systems were loam, sandy loam and silt loam. The dispersion ratio varied from 30.2 to 47.9, which was very high in all the land uses. It had significant positive correlation with sand (r=0.76**) and significant negative correlation with organic carbon (r= -0.74**) and clay (r=-0.56**). Erosion index ranged from 48.1 to 89.9, and the highest was observed under terrace land use and lowest under forest land use. Erosion index had significant positive correlation with sand (r=0.72**) and dispersion ratio (r=0.74**) and significant negative one with organic carbon (r=-0.69**) and clay (r=-0.68**). The dispersion ratio and erosion index of all the land uses were very high indicating that the soils are highly erodible.*

Key words: Land use, dispersion ratio, erosion index

INTRODUCTION

Soil is a vital resource that underpins food security and environmental quality, both essential to human existence. Essentiality of soil to human well-being is often not realized until the production of food drops or is jeopardized when the soil is severely eroded or degraded to the level that it loses its inherent resilience. Soil, being the main source of overall production system, the knowledge of variability in soil properties and adoption of site specific management, will enhance the productivity and study of variability of soil properties represents an important outset for precision agriculture. Land, being non expandable in nature, the availability of cultivable land becomes the most important and crucial factor limiting sufficient crop production for the ever increasing population. Moreover, worldwide food shortage has compelled the farmers to bring under plough, such soils which are not suitable for cultivation on the one hand, and ever increasing population has diverted some of the most productive soils for non-agricultural use in many regions on the other. In this context, judicious and optimum use of the scarce land resources and increasing its production and productivity per unit area per unit time through intensification of agriculture under scientifically tested and appropriate package of soil management practices assume a place of utmost significance. Soil degradation is a major problem and the mismanagement of soil and destructive land use can render the soil barren and uncultivable. The problems pertaining to improper land use can be rectified with proper planning and timely intervention. Implementation of conservation practices via. agronomical and engineering measures should be introduced and strictly followed for the land to check degradation. The variability of soil properties in Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram and Sikkim still remains to be critically evaluated. The lack of this basic information remains a bottleneck in the application of modern

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agricultural technologies and for finding alternatives to the main form of agriculture in the state i.e., shifting cultivation. *Jhum* or shifting cultivation is predominant in this region which is known to have a deleterious effect on soil properties and thus calls for a study on the variability of properties of soils to help equip the farmers with tools for maintaining the soil health and increasing the productivity. In Sikhe village of Arunachal Pradesh, the data related to the variability of soil properties was found lacking. Therefore, the present investigation was carried out to evaluate the important soil properties under different land uses.

MATERIALS AND METHODS

The soil samples were collected from Sikhe village under Lower Subansiri district of Arunachal Pradesh which is located between 27^0 33'-59' N latitude and 93^0 49'-53' E longitude. It has an average elevation of 1688 meters (5538 feet) above mean sea level and the climate of the study area is temperate to sub-tropical with mean annual temperature of 18^0 C. The minimum and maximum temperature ranges between -2 ^{0} and 35 ^{0} C and rainfall ranges from 1500 mm to 2000 mm per annum. Representative samples from depths of 0-15 cm were collected from three different portions i.e., upper, middle and lower portions of three different land use patterns, viz. land under *Jhum* cultivation, forest land and terrace land. In total, 45 bulk samples were collected. The soil samples were air-dried and processed for evaluating the various soil properties. The pH of soil was determined in 1: 2.5 ratio of water suspension. The organic carbon of the soil sample was determined by wet digestion method and cation exchange capacity (CEC) by NH_3 distillation method (Jackson, 1973). The bulk density of the soil was determined by the Pycnometer method. The water holding capacity of the soil was determined as per procedure outlined by Piper (1996). The hydraulic conductivity, per cent aggregation and mean weight diameter (MWD) of the soil were determined as described by Baruah and Barthakur (1997). The sand, silt and clay fractions of the soil samples were determined by the International Pipette method using 0.5N sodium hydroxide (NaOH) as a dispersing agent (Piper 1996). The value of dispersion ratio (DR) was computed by using the relationship suggested by Middleton (1930). Correlation coefficient was worked out in order to find out interrelationship among various soil characteristics following the procedure outlined by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Mechanical composition

The data on mechanical composition of soils of different land uses in Sikhe village are presented in Table 1. The soils of terrace, *jhum* and forest land uses were sandy loam, loam and silt loam, respectively. The highest sand content was in terrace land (66.49%) followed by *jhum* (37.23%). The soil samples collected from forest showed comparatively higher silt (52.40%) and clay (17.65%) followed by *jhum* (42.77% silt and 16.99% clay) and terrace (17.73% silt and 14.17% clay).

Table 1: Mechanical composition of soils under different land uses

Land use	Portion	Sand (%)	Silt (%)	Clay (%)	Texture Class
	Upper	66.49	17.99	13.56	Sandy loam
Terrace	Middle	66.85	17.55	14.12	Sandy loam
	Lower	66.12	17.64	14.83	Sandy loam
	Mean	66.49	17.73	14.17	Sandy loam
	Upper	37.12	42.74	17.33	Loam
Jhum	Middle	37.37	42.61	17.19	Loam
	Lower	37.21	42.97	16.46	Loam
	Mean	37.23	42.77	16.99	Loam
	Upper	28.26	52.26	17.89	Silt loam
Forest	Middle	28.04	52.89	16.79	Silt loam
	Lower	28.23	52.06	18.28	Silt loam
	Mean	28.18	52.40	17.65	Silt loam

Table 2: Chemical and physical characteristics of soils under different land uses

Parameter	Land use and portion											
	Terrace				*Jhum*				Forest			
	Upper	Middle	Lower	Mean	Upper	Middle	Lower	Mean	Upper	Middle	Lower	Mean
pH	5.4 (5.1-5.9)	5.5 (5.0-6.1)	5.4 (5.2-5.7)	5.4	5.5 (5.3-5.9)	5.5 (5.3-5.9)	4.9 (4.6-5.4)	5.3	5.0 (4.7-5.3)	5.5 (5.4-5.7)	5.2 (4.9-5.7)	5.2
Organic carbon (g kg^{-1})	12.3 (10.7-13.6)	13.1 (12.6-13.6)	15.1 (13.6-16.6)	13.5	29.8 (28.2-31.2)	29.4 (24.3-33.1)	27.5 (23.0-34.1)	28.9	32.3 (25.5-42.4)	38.5 (32.0-45.0)	35.8 (29.6-46.0)	35.5
CEC [c mol (p^{+}) kg^{-1}]	8.68 (7.90-9.20)	9.16 (9.00-9.40)	9.70 (9.40-10.10)	9.18	19.28 (16.50-21.30)	15.94 (13.40-21.80)	14.38 (12.90-16.30)	16.53	12.74 (10.10-18.40)	19.68 (16.10-23.70)	18.40 (12.10-22.70)	16.94
BD (g cm^{-3})	1.34 (1.23-1.45)	1.32 (1.19-1.47)	1.35 (1.15-1.56)	1.35	1.28 (1.27-1.33)	1.23 (1.22-1.25)	1.26 (1.23-1.28)	1.26	1.15 (1.12-1.19)	1.20 (1.18-1.23)	1.12 (1.10-1.13)	1.12
WHC (%)	45.8 (39.5-56.0)	52.1 (43.2-60.6)	50.5 (37.0-61.4)	49.5	58.8 (57.2-60.1)	56.0 (52.6-59.1)	57.5 (53.2-59.8)	57.4	60.1 (57.4-63.1)	59.3 (54.7-64.2)	57.6 (53.6-59.9)	59.0
Hydraulic conductivity (cm hr^{-1})	0.58 (0.21-0.94)	0.80 (0.61-0.98)	0.74 (0.35-0.96)	0.71	0.59 (0.33-0.88)	0.75 (0.45-0.86)	0.38 (0.11-0.79)	0.57	1.16 (1.01-1.37)	1.27 (1.02-1.86)	1.15 (1.02-1.40)	1.19
Percent aggregation (> 0.25 mm)	93.4 (91.6-96.0)	94.3 (93.6-95.2)	95.6 (94.4-96.8)	94.4	90.9 (89.0-95.0)	90.7 (89.0-93.6)	92.2 (91.0-95.8)	91.3	89.0 (87.0-91.0)	89.0 (88.0-91.0)	87.0 (83.0-89.0)	88.3
MWD(mm)	0.53 (0.52-0.55)	0.53 (0.53-0.54)	0.54 (0.53-0.59)	0.53	0.68 (0.60-0.79)	0.66 (0.58-0.79)	0.64 (0.57-0.77)	0.66	0.86 (0.84-0.88)	0.86 (0.83-0.88)	0.85 (0.80-0.88)	0.85
Dispersion ratio	43.9 (39.1-47.9)	41.5 (38.2-46.4)	44.2 (39.0-50.5)	43.2	39.4 (38.5-40.3)	38.3 (36.0-41.0)	39.5 (35.8-43.2)	39.1	34.1 (30.9-37.4)	32.2 (30.2-33.6)	34.2 (32.6-35.2)	33.5
Erosion index	75.2 (60.4-89.9)	76.4 (64.1-82.7)	73.8 (67.4-79.7)	75.1	67.0 (63.7-73.8)	62.4 (60.4-64.9)	69.4 (58.0-79.2)	66.3	57.6 (51.3-71.3)	57.2 (48.1-66.7)	54.0 (51.0-57.9)	56.3

Variability of soil chemical properties

pH: Data (Table 2) indicated that pH of all the soils were acidic in nature. The lowest (5.2) and highest (5.4) soil pH were recorded in forest and terrace soils, respectively. The soils under terrace cultivation which have higher pH could be due to rice straw and other organic residues on the terrace which could have prevented serious leaching of bases due to heavy rainfall. Similar results were reported by Sharma *et al.* (2012) and Deb *et al.* (2014) for the soils in some other North-Eastern regions.

***Organic carbon*:** The investigation revealed that the soils were rich in organic carbon content irrespective of land use.. The highest organic carbon content (46.0 g kg^{-1}) was recorded in lower forest portion and the lowest (10.7 g kg^{-1}) in upper terrace. Organic carbon had significant positive correlation with cation exchange capacity (r=68**) and water holding capacity (r=0.55*) and significant negative one with bulk density (r=-0.61*), sand (r=-0.72**) and erosion index (r=-0.69) (Table 3). The higher organic carbon content observed in forest land may be due to the presence of leaf litter, higher microbial activities and vegetative residues. Similar results were also reported by Ray *et al.* (2006) and Paul *et al.* (2011).

***Cation exchange capacity (CEC)*:** The soil samples collected from forest showed comparatively higher CEC [16.94 c mol (p^+) kg^{-1}] followed by *jhum* [16.53 c mol (p^+) kg^{-1}] and terrace [9.18 c mol (p^+) kg^{-1}]. The CEC of *jhum* and forest were higher than terrace field. The CEC showed a significant positive correlation with organic carbon (r=0.68**), silt (r=0.72**) and clay (r=0.57*) and significant negative correlation with sand (r=-0.72**) (Table 3). These findings are in conformity with those of Das *et al.* (2007) and Paul *et al.* (2011). The high CEC was substantially influenced by the organic matter and clay content of the soil.

Variability of soil physical properties

***Bulk density*:** The highest bulk density (1.56 Mg m^{-3}) was found in lower terrace and lowest (1.10 Mg m^{-3}) in lower forest. The average bulk density of terrace, *jhum* and forest were 1.34, 1.26 and 1.12 Mg m^{-3}, respectively (Table 2). Bulk density showed positive significant correlation with sand (r=0.67**) and dispersion ratio (r=0.73**) and significant negative one with water holding capacity (r=-0.77**) silt (r=-0.66**) and clay (r=-0.73**) (Table 3). The high bulk density in terrace could be due to presence of comparatively higher amount of sand in these soils. Similarly, low bulk density in forest soil could be due to presence of comparatively higher amount of finer fractions in these soils. Similar finding was reported by Ray *et al.* (2006), Gupta *et al.* (2010), Jalalzai *et al.* (2012) and Ajibola *et al.* (2018).

***Water holding* capacity:** The maximum water holding capacity was recorded under middle forest (64.2%) and the minimum in lower terrace (37.0%). The averages of the water holding capacity of terrace, *jhum* and forest were 49.5, 57.4 and 59.0%, respectively (Table 2).

Table 3: Correlation coefficients among various soil properties

Parameters	pH	OC	CEC	BD	WHC	K	PA	MWD	Sand (%)	Silt (%)	Clay (%)	DR	EI
pH	1												
OC	-0.09	1											
CEC	0.11	0.68**	1										
BD	0.32	-0.61*	-0.38	1									
WHC	-0.32	0.55*	0.49	-0.77**	1								
K	0.06	0.42	0.16	-0.51*	0.28	1							
PA	0.00	-0.76**	-0.64**	0.61*	-0.41	-0.46	1						
MWD	-0.16	0.82**	0.59*	-0.67**	0.53*	0.59*	-0.82**	1					
Sand (%)	0.21	-0.91**	-0.72**	0.67**	-0.62*	-0.37	0.78**	0.86**	1				
Silt (%)	-0.21	0.91**	0.72**	-0.66**	0.61*	0.40	-0.79**	0.87**	-0.99**	1			
Clay (%)	-0.22	0.67**	0.57*	-0.71**	0.71**	0.35	-0.57*	0.65**	-0.77**	0.74**	1		
DR	-0.02	-0.74**	-0.58*	0.73**	-0.59*	-0.53*	0.69**	-0.78**	0.76**	-0.78**	-0.56*	1	
EI	-0.11	-0.69**	-0.53*	0.48	-0.20	-0.46	0.66**	-0.70**	0.72**	-0.72**	-0.68**	0.74**	1

**Significant at P=0.05, **Significant at P=0.01*

CEC = Cation exchange capacity, OC = Organic carbon, BD = Bulk density, MWD = Mean weight diameter, PA = Percent aggregation, DR = Dispersion ratio, EI = Erosion indices, WHC = Water holding capacity, and K = Hydraulic conductivity

The water holding capacity of soils under natural conditions was higher as compared to soils under cultivated conditions. This may be ascribed to better soil physical conditions and presence of high organic matter content. Similar result was reported by Ray *et al.* (2006)**.** Water holding capacity showed significant positive correlation with organic carbon content (r=0.55*), silt (r=0.61*), clay (r=0.71**) and mean weight diameter (r=0.82*) and significant negative one with sand (r=-0.92*) (Table 3). These findings are in agreement with those of Gupta *et al.* (2010), Singh *et al.* (2012) and Deb *et al.* (2014).

***Hydraulic conductivity*:** The hydraulic conductivity of terrace, *jhum* and forest soils ranged from 0.21 to 0.98, 0.88 and 1.01 to 1.86 cm hr^{-1}, respectively. The average hydraulic conductivity of terrace, *jhum* and forest were 0.71, 0.57 and 1.19 cm hr^{-1}, respectively (Table 2). The hydraulic conductivity had significant positive correlation with mean weight diameter (r=0.59*) and significant negative one with bulk density (r=0.51*) (Table 3). The highest hydraulic conductivity under forest land might be due to the influence of organic matter content. Similar observation was reported by Babhulkar *et al.* (2000).

***Percent aggregation (> 0.25 mm)*:** The soil samples collected from terrace showed comparatively higher per cent aggregation (94.4) followed by *jhum* (92.2) and forest (88.3). The highest percent aggregation was recorded in lower terrace (96.8) and lowest in lower forest (83.0). The higher per cent aggregation in cropped land could have been due to addition and accumulation of organic matter through organic manure and crop residues that together with clay and other soil constituents, favored particle aggregation. Similar findings were reported by Pramanik and Chakroborty (2007) and Ray *et al.* (2006).

***Mean weight diameter (MWD)*:** The MWD of soils under study varied between 0.52 and 0.88 mm. The average mean weight diameter of terrace, *jhum* and forest was 0.53, 0.66 and 0.85 mm, respectively (Table 2). The MWD showed a significant positive correlation with organic carbon content (r=0.82**) (Table 3). Similar findings were reported by Ray *et al.* (2006). The study revealed that MWD had higher values under forest which might be due to the influence of organic matter, clay fractions and soil porosity. Similar results were also reported by Khera and Kahlon (2005) and Ray *et al.* (2006).

Variability of soil erodibility characteristics

***Dispersion ratio*: T**he highest dispersion ratio was recorded in the lower terrace (44.2) whereas, the lowest was found in the middle forest (32.2) soils. The average of the dispersion ratio of terrace, *jhum* and forest were 43.2, 39.1 and 33.5, respectively (Table 2). Dispersion ratio showed significant negative correlation with organic carbon (r=-0.74**) and clay (r=-0.56*) and significant positive one with sand (r=0.76**) (Table 3). According to the criterion of Middleton (1930); soils having dispersion ratio > 15 and erosion ratio > 10 are erodible in nature. So, the soils were found to be highly erodible under all land uses using above criteria. Khera and Kahlon (2005) also observed that forest soils and grassland soils had lower values of dispersion and erosion ratios as compared to bare and arable soils.

***Erosion index*:** The soil samples collected from forest showed comparatively lower erosion index (56.3) as compared to *jhum* (66.3) and terrace (75.1) soils (Table 2). Erosion index showed significant positive correlation with sand (r=0.72**) and dispersion ratio (r=0.74**) and significant negative one with organic carbon (r=-0.69**) and clay (r=-0.68**). The forest soils were less erosive in nature compared to *jhum* and terrace, which might be due to better physico-chemical parameter i.e. bulk density, hydraulic conductivity and organic carbon (Dutta *et al.* 2018).

The present study clearly indicated that the pH of the soils was moderate to acidic and organic carbon content was found to be high. The forest soils had a higher cation exchange capacity followed by *jhum* and terrace land use. The bulk density of forest was recorded lowest. The maximum water holding capacity was found under forest land use and the minimum under terrace land use system. The hydraulic conductivity of the soil was higher under forest land use as compared to *jhum* and terrace land use. Per cent aggregation was higher under terrace land use. Forest land use had a higher mean weight diameter. The dispersion ratio was higher in terrace land use as compared to *jhum* and forest. All the soils, irrespective of the land use, were found to be highly erosive. The erosion index was highest under terrace land use as compared to *jhum* and forest land use and this land use could be subjected to a higher degree of erosion. Erosion index of all land uses was recorded above the threshold limit (2.8) and qualified for erodible class. Therefore, proper agronomic and mechanical conservation measures should be adopted to prevent erosion and further land degradation. The results of the study can be used to make recommendation for proper management practices to maintain sustain productivity.

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