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Spatial Distribution of Plant Available Soil Nutrients in Different Landforms of Bongaigaon District, Assam

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Abstract: In order to assess the effect of landforms on availability of soil nutrients and to study the relationship between different soil chemical characteristics *viz.* pH, organic carbon (OC), available nitrogen (AN), phosphorus (AP) and potassium (AK), and DTPA-extractable micronutrients (Zn, Cu, Mn and Fe), soil samples were collected from four major landforms (hill side slopes, foot hills, flood plains and char lands). The results indicate that OC and AN had higher values (15.9 g kg^{1}, 218.5 g kg^{1}, respectively) in hill side slopes and lower values (15.9 g kg^{1} and 147.4 g kg^{1}, respectively) in char lands. There were significant differences in pH, OC, AK and AP with landforms, but the differences in values of pH, OC and AN between hill side slopes and foot hills were non-significant. There were inconsistent variations of DTPA-extractable Zn, Cu, Mn and Fe with respect to landform. Only Zn showed a significant difference between hill side slopes, flood plains and char lands. The application of principal component (PC) analysis on the investigated soil nutrients revealed three components with eigen values greater than 1, which explained 69.2 per cent variability. PC1, which had high positive loadings of pH, Zn, Mn and AP and moderate negative loadings of AK, accounts for 31.09 per cent of variance, and is the most important component. PC1 could be better explained by correlation study as there are significant negative relationships of soil pH with AP (r= 0.236) and Zn (r= 0.293), which indicates that these nutrients were the most limiting factors under sustainable management of soils of north eastern India.

Keywords: *Landforms, soil nutrients, multivariate analyses*

Introduction

There have been several attempts to relate soil properties to landscape positions (Ofori *et al.* 2013; Yumnam *et al.* 2013; Onweremadu *et al.* 2007; Reza *et al.* 2011). This may be partly due to the realization of the role of topographic position in influencing run-off, soil erosion and hence soil formation (Babalola *et al.* 2007). In addition to the organic carbon (OC) which varies with landscape (Hobbie 1996), landform and physiography influence soil texture and acidic cations (Stutter *et al.* 2004) and nutrient budget (Mallarino 1996). Hence, the landscape is important in fertilizer management (Paz-gonzalez *et al*. 2000); high yields and good product can be achieved only when the right type of soil is used for a certain crop. However, for areas in which suitable soil is not available, soil amendment may be done to facilitate the crop growth and optimum yield.

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The ability to produce food is the fundamental process in societal development therefore, it is necessary to study the availability and distribution of nutrients in soil for a better production (Saidou *et al.* 2004). A proper evaluation of the fertility of a soil before planting a crop helps in adopting appropriate measures to make up for the shortcomings and ensuring a good crop production. However, soil fertility decline is less visible and less spectacular and more difficult to assess (Belachew and Abera 2010).

The use of multivariate analytical methods in the soil science field is growing recently for example, finding a relationship between the soil classes and the nutritional state of some crops (Wadt 2005); deducing the categorical or continuous properties using the cluster technique (Simbahan and Dobermann 2006); determining the minimum number of soil properties that represent a class or category (Bockheim 2008); grouping the soil properties affecting crop productivity in lower Brahmaputra valley zone (Reza *et al.* 2015). The present study was undertaken to evaluate the effect of landforms/landscape on soil properties in landscape of Bongaigaon district, Assam, northeastern India. The findings of the study will help in taking up or formulating measures for enhancing and restoring soil fertility, which will lead to increase in crop productivity.

Materials and Methods

Study area and site selection

The area under study belongs to the Bongaigaon district of Assam (26°09′0"26°31′30"N, 90º22′30"90º52′15"E) covering an area of 1725 km^2. The climate is humid sub-tropical. The maximum temperature is 33ºC during July and August and minimum temperature falls up to 13ºC in the month of January. Annual rainfall is 2500–3500 mm. According to soil survey report, there are three broad soil sub-groups in the district namely Typic Dystrudepts, Typic Udipsamments and Typic Udifluvents (Sen *et al.* 1999). Soil sampling sites were selected within four major landforms (hill side slopes, foot hills, flood plains and Char lands) and soil sampling was carried under the project of "Soil Nutrient Mapping of Assam".

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Soil sampling and analysis

A total of 64 soil samples were collected from sixteen randomly located plots in each landform (16 locations × 4 landforms) from the entire district. The samples were air-dried, grounded to pass through a 2 mm sieve. Available potassium (AK) was extracted with 1*N* NH_4OAc and then measured by atomic absorption spectrophotometer. Available nitrogen (AN) was determined by the method of Subbiah and Asija (1956), OC by Walkley and Black (1934) and pH with glass electrode in a 1:2.5 soil/water suspension. Bray-1P (AP) was determined by colorimetric spectrophotometer (Bray and Kurtz 1945) and DTPA extractable micronutrients were determined by Lindsay and Norvell (1978).

Statistical analyses

All the statistical analyses were performed using SPSS 15.0 (SPSS Inc. 2006). One-way analysis of variance was performed to test the effect of landscape on soil nutrients. Fisher's least significant difference (LSD) t-test was performed to examine the significant differences between means. Principal component analysis (PCA) was performed on the values of soil nutrients after values have been subjected to linear correlation analyses to produce a correlation matrix.

Results and Discussion

Landforms and soil nutrients

Soil pH showed significant difference with respect to landform and increased down the slope from 4.8 to 7.0 from hill side slopes to flood plains, respectively (Table 1). The lower values of soil pH at the hill side slopes indicate that the acidity decreases down the slope. It may be due to prevalence of acidity at the upper slopes is an indication of strong chemical weathering and leaching of plants nutrients as reported by Babalola *et al.* (2007). According to Tsegaye *et al.* (2006), when rainfall percolate through the soil, it leaches basic cations such as Ca and Mg and replaces them first with acid forming cations such as H^{+}, Al^{3+} and Fe^{2+}, making them acidic. The mean values of soil nutrients in relation to landscape under the four major land forms are shown in table 1. There were significant differences in pH, OC, AK and AP with landforms, but the pH, OC and AN between hill side slopes and foot hill were non-significant (Table 1). Generally, OC and AN (15.9 g kg^{1}, 218.5 g kg^{1}) had higher values in hill side slopes due to dense vegetation (Panwar *et al.* 2011) and lower in char land (5.5 g kg^{1} and 147.4 g kg^{1}, respectively) due to fluvial activity and lighter texture. The higher concentrations of these nutrients at foot hill suggest that overland and surface run-off might have transported these soil nutrients to the foot slope. Similar findings have been reported by other researchers (Babalola *et al.* 2007; Onweremadu 2007 and Reza *et al.* 2011). The soil in the flood plain had higher AP (7.8 mg kg^{1}) followed by foot hill (6.0 mg kg^{1}), char land (4.5 mg kg^{1}) and lower in the soils of hill slope (4.0 mg kg^{1}), and these values differed significantly (Table 1) with respect to landform. The content of Zn (0.84 mg kg^{1}) and Mn (28.8 mg kg^{1}) were higher in hill slope and lower (0.41 mg kg^{1} and 11.0 mg kg^{1}, respectively) in flood plain. The higher content of Zn in the hill slope may be due to higher organic matter content and low pH (Reza *et al.* 2016). There were inconsistent variations of DTPA-extractable Zn, Cu, Mn and Fe with respect to landform. Only Zn showed a significant difference between hill slope, flood plain and char land.

Table 1. Soil nutrients in relation to landscape position

Landforms	pH	OC	AN	AK	AP	Cu	Zn	Mn	Fe
		g kg^{-1}		mg kg^{-1}					
hill side slopes	4.8^{a}	13.8^{a}	202.7^{a}	33.3^{a}	4.0^{a}	2.8^{a}	0.84^{a}	28.8^{a}	63.0^{a}
Foot hills	4.9^{a}	15.9^{a}	218.5^{a}	74.7^{b}	6.0^{b}	3.7^{a}	0.56^{ab}	16.0^{ab}	63.3^{a}
Flood plains	7.0^{b}	5.6^{b}	176.5^{ab}	57.5^{b}	7.8^{b}	3.6^{a}	0.40^{b}	11.0^{b}	32.8^{b}
Char lands	6.9^{b}	5.5^{b}	147.4^{b}	39.2^{c}	4.5^{c}	3.3^{a}	0.41^{b}	21.3^{ab}	56.4^{a}

Note: Mean values in each column with the same letter are not significantly different ($P < 0.05$, LSD)

Relationship between soil nutrients

The data in table 2 indicated that principal component analysis (PCA) reduced 9 variables to 3 orthogonal components with eigen values greater than unity. These three components altogether explained 69.2 per cent of the total variance within the variables. For the purposes of determining interrelationships, factor loadings between 0.50 and 0.75 were defined as "moderate", loadings >0.75 were defined as "high", and loading <0.5 were defined as "low" (Stamatis *et al.* 2011).

In details, principal component 1 (PC1), which had high positive loadings of pH, Zn and AP and moderate negative loadings of AK, and accounts for 31.09 per cent of variance (Table 2), and is the most important component. PC1 could be better explained by correlation study (Table 3) as there are significant negative relationships of soil pH with AP (r= 0.236) and Zn (r= 0.293). A similar correlation was also reported by

Deka *et al.* (2012) for the northern Brahmaputra valley soils of Assam. PC2 had moderate positive loadings of OC, AN and AK, accounts for 23.34 per cent of variance. Correlation study also showed that OC was significantly positively correlated with AN (r= 0.338) and AK (r= 0.315). There have also been reports on a positive relationship between OC and the capacity of the soil to supply essential plant nutrients including AN and AK (Rezaei and Gilkes 2005). PC3 had moderate positive loadings of AP and low negative loading of Fe and accounts for 14.79 per cent of variance. In this study pH, Zn and AP had an over-riding influence on other 9 variables investigated. Earlier studies (Sen *et al.* 1997; Reza *et al.* 2012a; Reza *et al.* 2012b) also showed that, these nutrients were most limiting factors under sustainable management of soils of Assam and which can be explained by high positive loadings of these variables in PC 1 in this study.

Table 2. Principal component analysis of soil nutrients

Soil properties	PC1	PC2	PC3	Communities
pH	0.855	0.301	–0.151	0.792
OC	0.176	0.686	0.464	0.782
AN	–0.037	0.640	–0.079	0.517
AK	–0.591	0.520	0.167	0.540
AP	0.751	–0.115	0.516	0.800
Cu	–0.489	0.527	0.030	0.469
Zn	0.844	–0.001	0.067	0.552
Mn	0.301	0.816	–0.226	0.677
Fe	0.187	–0.645	–0.407	0.634
Percentage of variance	31.09	23.34	14.79	
Cumulative percent	31.09	54.43	69.22	

Table 3. Correlation between soil nutrients

	pH	OC	AN	AK	AP	Cu	Zn	Mn	Fe
pH	1.000								
OC	–0.726**	1.000							
AN	–0.299*	0.338**	1.000						
AK	0.359**	0.315*	0.117	1.000					
AP	–0.236*	–0.336**	–0.039	–0.508**	1.000				
Cu	0.117	0.016	–0.026	–0.235	0.006	1.000			
Zn	–0.293*	0.329*	0.055	0.385**	–0.229	0.087	1.000		
Mn	–0.163	0.152	–0.010	0.319*	–0.415**	0.041	0.581**	1.00	
Fe	–0.359**	0.201	–0.118	–0.043	–0.368**	0.105	0.298*	0.345**	1.000

**Significant at the 0.01 level; *Significant at the 0.05 level

Conclusion

Soil nutrients varied among the landforms. Soils were, generally, acidic in nature, low in AP, and DTPA-extractable Zn. Soil pH showed significant difference with respect to landform and increased down the slope. The soil in the flood plain had higher AP followed by foot hill, char land and lower in the soils of hill slope. The content of Zn and Mn were higher in hill slope and lower in flood plain. Principal component and correlation matrix used in this study provide important tools for better understanding the soil fertility potential.

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