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Original Research Article

SOIL CHARACTERISTICS IN DIFFERENT AGES OF PLANTATION AND NATURAL FOREST IN TERAI ARC LANDSCAPE OF UTTAR PRADESH, INDIA

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ABSTRACT

The objective of this paper was to determine the physicochemical properties of soil at plantation (done by the Taungya system) and natural forest in the Terai of eastern Uttar Pradesh. Soil samples were collected from both the different sites of 25yr, 50yr and 75 yr of the plantation and natural forest and analyzed for texture pH, water holding capacity, bulk density, organic carbon, total nitrogen and available phosphorus. Both the forest had the sandy loamy type of texture containing 60.20% of sand, 27.13% Silt and 12.66% clay in plantation and 49.00% sand, 32.00% silt and 19.00% clay in forest soil. Soils under different sites have been markedly differing in their content of organic carbon, nitrogen, and phosphorus. As the higher level of nutrients in natural forest shows that it is much nutrient rich compared to the plantation forest.

KEYWORDS: Terai Arc Landscape, natural forest, plantation, Taungya system, soil texture

INTRODUCTION

In recent centuries, Human activities have fundamentally altered many of the earth's biogeochemical cycles. According to a report of ICAR, 187.7 million hectares (57.1%) of the geographical area has been affected by various type and degree of land degradation in India (Faroda and Singh, 1997). Land degradation is a major problem all through the developing countries of South Asia including Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. Studies in the tropics have shown significance changes in soil organic

matter following conversion of natural forest into cultivation and these changes have been shown to affect soil fertility (Brown and Lugo, 1990; Dominy *et al*., 2002; Yimer *et al*., 2007). Half of the tropical soil in the world is highly weathered, leached and impoverished, and therefore mechanisms to conserve nutrient in the ecosystem are important (Sanchez 1976, Jordan, 1985). Reimbursement of forest and their consequent conversion into croplands deprives soils its water holding capacity, composition stability and compactness, nutrient supply and storage as well as its biological life (Rasiah et al., 2004). Forest soils persuade the composition of the forest stand and ground cover, rate of tree growth, the vitality of natural reproduction and other silviculturally significant factors (Bhatnagar, 1965). This has led to studies of soil properties under forest plantations in comparison to natural forests, pastures, natural savannas and croplands all over the world including Brazil, Australia and India (Lilienfein et al., 2000; Hartemink, 2003; Jobbágy and Jackson, 2003; Mishra et al., 2003;Turner et al.2005). The changes that occurred after deforestation and subsequent cropping are decreases in plant nutrient availability (Lu et al., 2002), decreases in microbial activity (Sahani and Behera, 2001), increases in bulk density, soil erosion and runoff (Rasiah and Kay, 1995) and decreases in water holding capacity (Lu *et al*., 2002; Sahani and Behera, 2001). Forest soil influences the composition of the forest stand and ground cover, the rate of tree growth, vigor of natural reproduction and other silviculturally important factors (Bhatnagar, 1965). Although the area of forest plantations has increased, there has been concern over their ecological and environmental effects. It is believed that: they carry on a low diversity of wildlife; they are high consumers of water and nutrients and increase soil acidification. Few reports have described the historical changes in soil and environmental aspects of Rwanda. The few soil chemical assessments were conducted on large land areas with many soil types, land uses, climatic and agroecological zones (Verdoodt and Van Ranst, 2003).

In Terai arc landscape (TAL) of eastern Uttar Pradesh, the large scale of natural forest has been converted to the plantation by Taungya system (mainly of *Shorea robusta*). There has been no much more study conducted so far related to the impact on soil due to the conversion of natural forest to the plantation. Currently in this chapter soil physicochemical characteristics was assayed for the natural forest and Plantation (at the different ages).

MATERIALS AND METHODS

1 The study area, climate and vegetation: The study area falls under, Gorakhpur and Maharajganj districts and or forest divisions of TAL (26º13'-27º 29' N latitude & 83º05'-83º56' E longitudes; elevation 82-90m amsl) in eastern corner of the state of Uttar Pradesh, India. Out of total area of these districts ca. 17% is occupied by forests. The subtropical climate of the study area is represented three seasons during annual period – summer (March- June), rainy (July – October) and winter (November- February. Total annual rainfall during the study period is 1359 mm of which 71% occurs during the rainy season. The average mean monthly maximum and minimum temperature during the winter season are 26^0C and 12^0C, during rainy season 32^0C and 24^0C and in summer season 35^0C and 22^0C, respectively. The soil is yellowish black in color.

The forest of the TAL has been described as northern tropical moist deciduous and semi-evergreen forests (Champion and Seth, 1968). *Shorea robusta* and *Tectona grandis* are dominant amongst tree species (Pandey and Shukla, 2003). Although, TAL represents only <1% of the geographical area of India but support >23 million peoples (ca. 70% area is under use for agriculture and settlement) and 13 protected areas (Semwal, 2005). In TAL during British period Taungya system was introduced by forest department which involves timber plantation in forests with the help of locals and in lieu, they were allowed to grow crops within forest areas. Presently, Taungya system has been suspended by the government and TAL constitutes mosaic composed of grasslands, savannas and deciduous and evergreen forests.

2. Soil sampling: Samples have been collected from the natural forest sites, all sites of (Plantation 25yr, 50 yr, and 75 yr). In all the sites three samples have been collected up to 15 cm depth which was separated by the ten meters distance from each other. The collected sample was packed in a polythene bags and taken to the laboratory for the analysis. All soil samples were individually homogenized air dried, ground and passed through the 2mm wire mesh to remove the fragments such as stones, plants parts and further replicated soil samples from the different area were analyzed.

3. Soil analysis: Following analytical process has been used for the soil analysis:

Soil bulk density was determined with the help of metal tube of known volume. Moisture content was estimated by drying the soil at 105°C. Soil pH was measured through the digital pH meter. (1 g soil: 5ml water). Water holding capacity was measured by the Brass box method given by the Piper (1966). Soil organic carbon was estimated by the walked and Black's method

(Walkely and Black, 1934). Total soil Nitrogen was estimated by the micro-Kjeldahl method (Jackson, 1958). Available phosphorus was estimated by the Olesen's method (Hesse, 1994).

4 Statistical analyses: The data of the soil physicochemical properties were analyzed by ANOVA test for examining the effects changes in the plantation and natural and their interactions on various parameters. Pearson's correlation test was used to explore the correlations among changes in various parameters. The entire statistical tests were performed using the SPSS software (SPSS Inc., version 10.0).

RESULTS

The result showed that the soil content affected by the plantation as there is changes occur from the natural forest to the plantation. Both the forest had a sandy loam type of soil texture. The soil of the natural forest having sand (49.00% ±2.08%), silt (32.00% ±1.15%) and clay (19.00% ±1.52%) and the plantation forest having a sand (60.20% ±1.87%), Silt (27.13±%1.30%) and clay (12.66%±1.01%) as shown in (Fig1).

The soil in all the four stands was acidic, but it was more acidic in plantation than in the natural forest (6.20±0.20). Comparing in the plantations 25 yr was more acidic (5.30±0.05) followed by the 50 yr (5.90±0.05) and the 75 yr (6.05±0.17). pH has been observed (Table 1). The water holding capacity was lower in the plantation than those in the natural forest (42.50% ±3.50%). In plantation 50 yr showing a higher WHC (38.25%±0.75%) followed by 50 yr plantation (34.30%±0.70%) and 25 yr plantation (24.19%±2.17%). Bulk density was almost similar in all the sites, natural forest showing a slightly higher (1.23±0.02 g/cm^3) and in 75 yr plantation (1.19±0.01g/cm^3) followed by 50 yr plantation (1.15±0.01 g/cm^3), 25 yr plantation (1.11±0.14 g/cm^3).

The percentage of organic carbon was rich in the natural forest (2.14%±0.17%) than the soil comparing to all the three sites of the plantation. In 25 yr plantation (0.80%±0.02%), 50 yr plantation (1.08%±0.05%), 75 yr plantation (1.22%±0.03%). This result shows that as the age of the trees was increasing organic carbon were increasing. The mean soil nitrogen content in all the sites was more or less similar, slightly higher in natural (0.12%±0.04%) than in the 75 yr plantation (0.06%±0.00%), 50 yr plantation (0.05%±0.00%) and 25 yr plantation (0.02%±0.00%). The C/N ratio was higher in 25 yr plantation (40.00) followed by 50 yr plantation (21.60), 75 yr plantation (20.00) and natural (17.83).

The mean value of available phosphorus in the soil of natural site was 3.52±0.16 mg/m^3. In plantation sites very low available phosphorus was observed in 25 yr plantation (1.6±0.23) mg/cm^3, 50 yr plantation (0.96±0.56 mg/m^3) and higher in 75 yr plantation(2.86±0.49 mg/m^3). The correlation analysis at all the sites among the different soil parameters showed a positively correlated with each other (Table 2).

DISCUSSION

On the basis of vegetation composition and dominance of different plant species the forest were categorized into natural and plantation forest. The natural forest was very rich in vegetation compare to the plantation which is consisting of only a few species. All the site area was highly dominated by the *Shorea robusta* and other major associated species were *Tectona grandis, Syzygium cumini, Aegele marmelos, Mallotus Philipensis* and *Adina cordifolia.*

Soil texture in plantation and the natural forest was of a sandy loamy type, which is suitable for good *Shorea robusta* regeneration and high-quality trees (Gupta, 1951, Paudel and Shah, 2003). This sandy loamy texture is very common in terai area, in Siwalik and Dun valleys, all of which support dense sal forest and other valuable timber trees (Shah, 1999). The pH condition of the site's soil revealed that the soil of the forest was acidic in all the three stands of the plantation and in the natural forest as it was also reported by the Shrestha (1992). The pH range was in the range as reported by the Sigdel (1994). Comparing the pH of the plantation to the natural it was observed that the pH was low in plantation it might be due to the vegetation structure or due to the high number of sal trees as reported by Bhatnagar, (1965).

The values of water holding capacity for all the study sites were ranged from 24.19% to 42.50%, which is lower than that in the eastern Nepal (43.03 to 49 %) (Paudel and shah 2003) and higher than that in the *Pinus roxburghii* forest (9%) and in oak forest (17%) in Garhwal Himalaya (Shah *et al*., 1994). This water holding capacity value was vary due to the coarser soil texture and it has been said by Panchal and Pandey (2002) that decline of water-holding capacity of the soil, resulted from depletion of clay particle of soil with detritions of the ecosystem which causes progressive drier condition of soil and reduction in plant density. The values of Bulk density was in between 1.10 to 1.23 which was more or less similar to the others finding.

Deforestation hastens soil organic matter less by altering of micro climate and coverage to microbial decomposition. The percentage of organic carbon in the surface soil under the plantation sites was in between (0.80%-1.22%) which is very less to the percentage of carbon

present in the natural forest. The depletion of total nitrogen was in the range between (0.02%-0.06%) same results have been observed by others during reforestation (Xu *et al*., 2000). This result shows that the soil surface under the natural forest had a significantly higher organic carbon and total nitrogen then in the soil under the plantation, which is due to the higher accumulation of the organic matter of the litter fall and root biomass and reduced rate of the litter decomposition rate (Paul *et al*., 2002, Jaiyoba, 2003). Apart from the natural forest, forest soil under the 75 years old plantation having a significantly higher organic carbon and nitrogen, these results shows that higher accumulation of litter and root biomass compare to the plantation of the 50 years and 25 years (Goma- Tchimbakal and Bernhard-Reverse, 2006, Yimer et al. 2007). The low nitrogen content in the forest soil is due to the higher mineralization.

In the plantation stand the C: N ratio was almost similar. This fidelity compared to the natural forest may indicate that the soil organic matter quality was more affected during the succession than the organic matter quality. At last, it concludes that the organic matter reached that of the natural forest after several decades as it was also reported by the Goma- Tchimbakala and Makosso (2008). It has been considered that the soil organic matter is the major pool of carbon and nitrogen, which regulate the larger extent of the physical, chemical and biological properties of the soil (Miller, 1990; Gupta and Malik, 1996). The decline of phosphorus concentration with the deterioration of ecosystem can be attributed to a depletion of clay particles and organic substances (Panchal and Pandey, 2002).

Soils under the different sites have been markedly differing in their content of organic carbon, nitrogen, phosphorus. Assuming that the natural forest showing a much rich in nutrient comparing to the plantation.

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Table.1: Soil variables tested for soil under different ages of the plantation and natural forest in the TAL of Uttar Pradesh.

	Plantations			Natural forest
Parameters	25 yr	50 yr	75 yr	
pH	5.30 ±0.05	5.90±0.05	6.05± 0.17	6.20 ±0.20
Water holding	24.19 ±2.17	34.3 ± 0.70	38.25±0.75	42.50 ±3.5

capacity				
Bulk density (g/cm^3)	1.11 ±0.01	1.15 ±0.01	1.19±0 .01	1.23 ±0.02
Organic Carbon (%)	0.80±0.02	1.08±0 .05	1.22± 0.03	2.14 ±0.17
Total nitrogen (%)	0.02 ±0.00	0.05 ±0.00	0.06 ±0.00	0.12 ±0.04
C:N Ratio	40.00	21.60	20.00	17.83
Available phosphorus (mg/cm^3)	1.6±0 .23	0.96 ±0.56	2.86 ±0.49	3.52 ±0.16

Table.2: Correlation coefficient among different soil parameter

	PH	WHS	BD	C	N	P
PH	1.000					
WHS	0.678*	1.000				
BD	0.837**	0.944**	1.000			
C	0.073^{ns}	0.641^{ns}	0.487^{ns}	1.000		
N	0.626^{ns}	0.907**	0.850*	0.798**	1.000	
P	0.733*	0.773*	0.721*	0.455^{ns}	0.847**	1.000

* Significant at the 0.05, ** Significant at the 0.01

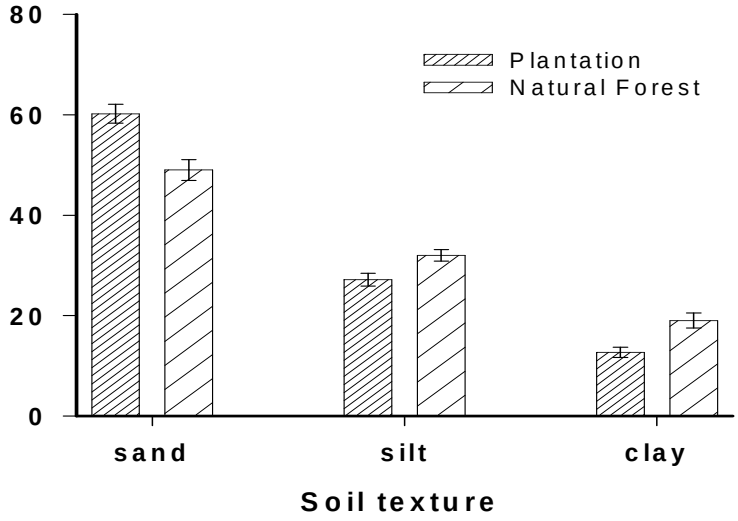

Figure: 1 Soil particle size distribution (%) at the plantation and Natural forest in the Terai Arc landscape of Uttar Pradesh.

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