Physiochemical characteristics of soil in tropical sal (*Shorea robusta* Gaertn.) forests in eastern Nepal

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The physiochemical properties of soils of two different types of forests (pure *Shorea robusta* and mixed *Shorea robusta*) were analyzed. Soil samples were collected from both types of forest and analyzed for texture, pH, organic matter, humus content, water holding capacity, nitrogen, phosphorous and potassium. In both the pure and mixed forest, soil was sandy loam (60.12% and 50.58% sand, 28.59% and 35.24% silt and 11.12 and 22.41% clay, respectively). The pH value was lower in pure forest (4.33) than in the mixed forest (5.26), and so were phosphorus and water holding capacity. The higher values of humus, organic matter, nitrogen and potassium (7.34%, 2.42%, 0.117%, 267.73 kg/ha, respectively) were found in pure forest. The higher levels of soil nutrients in the pure forest were due partly to reduction in the loss of top soil and partly to the increased supply of nutrients in the form of leaf litter and biomass from the larger number of sal trees and their saplings.

Key words: *Shorea robusta*, soil texture, nitrogen, soil pH, Udayapur

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Introduction

Forest soils influence the composition of the forest stand and ground cover, rate of tree growth, vigor of natural reproduction and other silviculturally important factors (Bhatnagar 1965). For instance, growth of *Shorea robusta* (sal) and other tree species, such as *Terminalia alata* and *Syzygium cumini*, in tropical forests is highly influenced by nitrogen, phosphorus, potassium, and soil pH (Bhatnagar 1965). Physiochemical characteristics of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic variables. Vegetation plays an important role in soil formation (Chapman and Reiss 1992). For example, plant tissues (from aboveground litter and belowground root detritus) are the main source of soil organic matter (OM), which influences physiochemical characteristics of soil such as pH, water holding capacity (WHC), texture and nutrient availability (Johnston 1986). Nutrient supply varies widely among ecosystems (Binkley and Vitousek 1989), resulting in differences in plant community structure and production (Ruess and Innis 1977, Chapin et al. 1986). Organic matter supplies energy and cell building constituents for most microorganisms (Allison 1973) and is a critical factor in soil fertility (Brady 1984).

The vegetation zones in Nepal clearly reflect edaphic variations (Bhatta 1981). The Terai region is characterized by alluvial soil, which is transported by the river systems. River deposits more sand and silt than clay in the flood plains of the Terai that support the dense forests of sal and other valuable timber trees. However, the sal forests are in a degraded state in terms of both density as well as ground vegetation because of indiscriminate cutting, recurring forest fire and uncontrolled grazing. In fact, more than 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). The objective of the present study was to document the physiochemical characteristics (WHC; pH; soil texture; N, P, K, OM and humus content) of soil in two separate and dissimilar sal forests: a pure stand of *S. robusta* managed by the local community, and a mixed *S. robusta* forest managed by the government.

Materials and methods

Study area

The study was carried out in April and May 1998 in Ward 6 of Triyuga Municipality in Udayapur district of eastern Nepal (86°9'-87°10' E, 26°39'-27°11' N), and comprised the pure *S. robusta* Sanua Sukanahi community forest as well as the mixed Banke Danda national forest. The elevation of the site ranges from 210 to 250 m asl. The soils are non-sticky sandy loam because the geological formation of the district lies in the Siwalik zone (Nepal District Profile 1997). Though the study area has a tropical monsoon climate and receives a great deal of rain, the area seems somewhat arid because most of the rainfall flows away quickly as surface run-off, allowing the soil to dry quickly. These are ideal conditions for sal (*S. robusta*), which grows poorly in water logged soil (Stainton 1972).

Soil sampling

Soil was taken from 15 cm deep cores. It was collected from 30 randomly distributed sites in each of the pure and mixed forests. The collected soil samples were packed in polythene bags and taken to the laboratory for analysis. Soil analyses were performed at the Central Department of Botany, Tribhuvan University, and the Nepal Agriculture Research Council (NARC), Kathmandu. Soil texture was determined by the hydrometer method (PCARR 1980) and the texture group was determined by means of a texture triangle (USDA system). Organic matter and humus content were determined using the methods described in PCARR (1980). Total nitrogen content was determined by means of the Kjeldalel method. Phosphorus was determined using the Truog method; potassium content by flame photometer; and soil pH by the potentiometric method, using a digital pH meter and sampling soil and water in a 1:1 ratio (PCARR 1980). Humus content and WHC were calculated by using the following formula (cf Zobel et al. 1987).

$$\text{Humus content (\%)} = \frac{\text{Weight of humus}}{\text{Weight of soil}} \times 100$$

$$\text{Water holding capacity (\%)} = \frac{\text{Water retained by the soil at saturation}}{\text{Weight of dry soil}} \times 100$$

Data analysis

To find the relationships between the parameters of soils of these forests, the correlation coefficient was calculated following the formula used by Pearson (1957).

$$\frac{\sum xy - \frac{\sum x.\sum y}{n}}{\sqrt{\left(\sum x^2 - \frac{\left(\sum x\right)^2}{n}\right)\left(\sum y^2 - \frac{\left(\sum y\right)^2}{n}\right)}}$$

Results

Vegetation of the study area was dominated by the *S. robusta*. Both forests had similar types of plant species composition. The pure *S. robusta* was forest composed predominantly of *S. robusta*, in association with *Adina cordifolia*, *Schleichera oleosa*, *Swida oblonga*, *Semecarpus anacardium*, and other species. In the mixed *S. robusta* forest, *S. robusta* and *Terminalia alata* were equally dominant. Other associated species included S*yzygium cumini*, *Bombax ceiba*, *Acacia catechu*, *Schleichera oleosa*, and *Semecarpus anacardium*.

Both forests had sandy loam type of soil texture. The soil of pure *S. robusta* forest was composed of sand (60.12%±3.59%), silt (28.59%±3.18%), and clay (12.24%±1.62%); while the proportions for the mixed *S. robusta* forest were 50.58%±5.84%, 35.24%±4.54%, and 22.41%±3.20%, respectively **(Figure 1)**.

Soil in both forests was acidic. It was more acidic in the pure *S. robusta* forest (pH = 4.33±0.39) than in the mixed *S. robusta* forest (5.26±0.58) **(Figure 2)**. The soil in mixed *S. robusta* forest had higher WHC (49.80%±6.30%) than that in pure *S. robusta* forest (43.03%±3.02%).

The humus content of the soil in the two forests was not noticeably different: the value was only slightly higher in the pure *S. robusta* forest (7.34%±1.47%) than in the mixed *S. robusta* (5.5%± 0.99%) forest **(FIGURE 2)**.

The average organic matter content in the soil of the pure *S. robusta* forest was 2.42%±0.39%, compared to 1.74%±0.31 in the mixed *S. robusta* forest **(Figure 2)**.

The mean soil nitrogen content in both forests was more or less similar, slightly higher in pure *S. robusta* forest (0.117%±0.01%) than in mixed *S. robusta* forest (0.111%±0.01%) **(Figure 3)**.

The mean value of available phosphorus in the soil of the pure *S. robusta* forest was 76.64±4.95 kg/ha, slightly less than the 79.29±3.92 kg/ha found in mixed *S. robusta* forest **(Figure 3)**. The mean value for potassium was higher in the pure *S. robusta* forest than that in the mixed S. *robusta* forest, available potassium in the soil of the *S. robusta* forest was 267.73±29.93 kg/ha, compared with 233.86±18.43 kg/ha in the mixed S. *robusta* forest was **(Figure 3)**.

The correlation analysis among the different soil parameters showed that the pH was negatively correlated with organic matter (r = –0.311) and nitrogen (r = –0.422), whereas there was positive correlation between pH and all other parameters such as humus content, water holding capacity, phosphorus and potassium content **(Table 1)**. However, none of these correlations were found statistically significant.

Organic matter was slightly negatively correlated with potassium (r = –0.052) and WHC (r = –0.030), while it was slightly positively correlated with nitrogen, phosphorus and humus content. However, these correlations were not found statistically significant either. Nitrogen showed significant negative correlation with phosphorus (r = –0.610) and positive correlation with potassium (r = 0.903). It also showed positive correlation with WHC and negative correlation with humus content. Phosphorus showed significant positive correlation with potassium (r = 0.519).

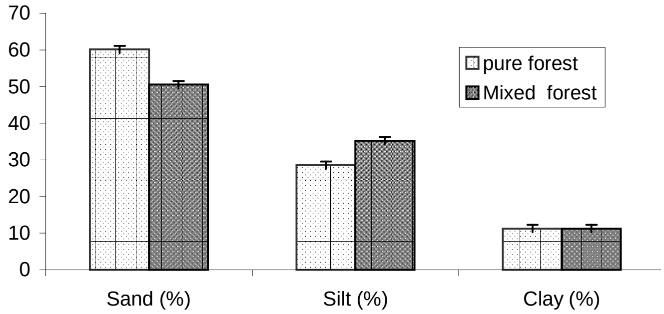

FIGURE 1. Soil texture in the forest

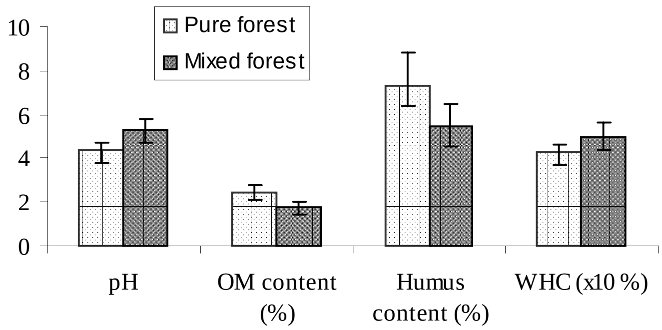

FIGURE 2. Different soil parameters

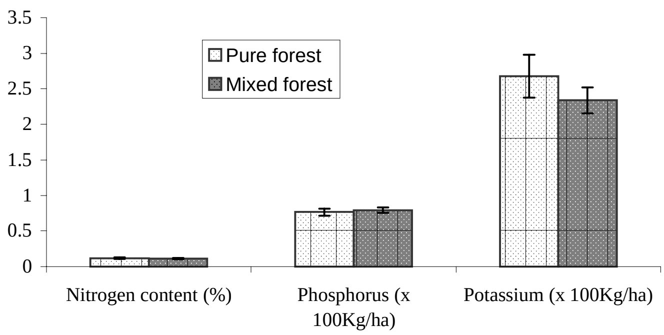

FIGURE 3. Different soil parameters

Discussion

On the basis of vegetation composition and dominance of different plant species, forests were categorized into pure and mixed *S. robusta* forests. The pure *S. robusta* forest (managed by the local community) was highly dominated by *S. robusta*, while the mixed *S. robusta* forest (government managed, with free access for local people), was heterogenous and equally dominated by *S. robusta* and *Terminalia alata*. Other major associated species were *Semecarpus anacardium*, *Adina cordifolia*, *Syzygium cumini*, *Bombax ceiba* and *Acacia catechu*.

Soil texture in both the forests of the study area was of the sandy loam type, suitable for good sal regeneration and high quality trees (Gupta 1951). This sandy loam texture is very common in the Terai, and in Siwalik and Dun valleys, all of which support dense sal forests and other valuable timber trees (Shah 1999). The supply of water to plants usually is greater as the texture becomes finer (Black 1968). Soil texture also affects the nutrient supply of the soil. The present result is similar to the finding of Shrestha (1997) in Chitrepani, Sigdel (1994) in Royal Chitwan National Park (RCNP), Rana et al. (1988) and Gupta and Shukla (1991) in sal forests in India. This may be due to the similar type of forest vegetation, i.e., *S. robusta* dominated forest.

Soils in the forests were acidic in nature. Shrestha (1992) reported that in the Terai most of the soils are acidic. However, in the present study pure *S. robusta* forest soil was found to be more acidic than that of mixed *S. robusta* forest. The pH range in the present study was lower than the values reported by Sigdel (1994) in Royal Chitwan National Park (5.90-6.42), by Karki (1999) in Koshi Tappu Wildlife Reserve (6.4-7.1), or by Singh and Singh (1985) in *S. robusta* dominant central Himalaya forests (6.7-6.8). This may be due to local environmental factors such as aspect, rainfall, and vegetation composition. However, the values observed in this study were more or less similar to those reported by Singh and Singh (1989). They reported a pH range of 4.5-5.5 in the sal forest and concluded that this range is propitious for sal sapling growth. Good sal regeneration areas have low pH in soils (Bhatnagar 1965). The finding of higher acidity in the sites is consistent with other observations (Banerjee et al. 1986, Singh et al. 1987). Soils with higher pH generally have poorer capacity for regeneration (Suoheimo 1995). The low pH value in the present study area may be due to the continuous decomposition of surface litter over six years. The lower pH in the pure *S. robusta* forest than in the mixed *S. robusta* forest is probably due to higher number of sal trees and their saplings (Bhatnagar 1965), and the accumulation of leaf litter as well. The acidic nature of the soil at our study site may be attributed to the high rainfall, which is sufficient to leach basic cations from the surface horizons of the soils. Similar result was reported by Miller (1965).

Humus content was more or less similar in both forests, as was organic matter content. The latter ranged from 1.74 to 2.42%, comparable to the 1.74-2.33 range that, according to Suoheimo (1995), is indicative of low soil fertility. Brady (1984) mentioned that the higher soil organic matter occurred more commonly in cooler than warmer climates such as that of our study area. This may explain the occurrence of relatively low organic matter content in the soil despite the fact that litter had been accumulating over six years, especially in the pure *S. robusta* forest. Out of these two studied sites, pure *S. robusta* forest had higher organic matter content than the mixed *S. robusta* forest which may be because of more litter accumulation and decomposition in the former. Tamhane et al. (1964) mentioned that decomposing litter adds organic matter to the soil. It was seen that local people frequently visit the mixed *S. robusta* forest to collect forest products because in the pure *S. robusta* forest restrictions have been imposed on the exploitation of forest products. While, organic matter in the present study area was lower than the value (1.8-4%) reported from the forests in Riyale (Shrestha 1996), but within the range (0.23-1.8%) reported by Sigdel (1994) for Royal Chitwan National Park. Aweto (1981) reported that organic matter content increases with the maturation of forest. The mixed *S. robusta* forest is more mature, and might therefore be expected to contain more organic matter, than that of the pure *S. robusta* forest, but our data does not confirm this expectation, probably because the pure *S. robusta* forest had been protected for the previous six years, and litter collection had not been as intensive as in the mixed forest, and also due to the low organic input from the vegetation cover in the mixed *S. robusta* forest.

TABLE 1. Correlation coefficient among different soil parameters

	PH	OM	N	P	K	WHC
OM	-0.311					
N	-0.422	0.356				
P	0.196	0.262	-0.610			
K	0.210	-0.052	0.903	0.519		
WHC	0.197	-0.030	0.104	0.330	-0.225	
Humus	0.163	0.015	-0.125	0.063	-0.314	-0.241

OM= Organic matter, N= Nitrogen, P= Phosphorus, K= Potassium, WHC= Water holding capacity

The value of WHC for both forests ranged from 43.03 to 49.80%. According to Bhatnagar (1965), the WHC of soils from sal regeneration areas is higher. WHC in the present study area was higher than that in the *Pinus roxburghii* forest (9%) and in Oak forest (17%) in Garhwal Himalaya (Sah et al. 1994). Despite the higher organic matter and humus content in the pure *S. robusta* forest than in the mixed *S. robusta* forest, the WHC value was less in the former, probably because of the coarser soil texture; the pure *S. robusta* forest had more sand than the mixed *S. robusta* forest.

The nitrogen content of soil did not differ significantly in the two forests, and was similar to the values reported in other forests such as Chitrepani (0.04-0.09%) (Shrestha 1997). The value of soil nitrogen was less than the value reported from the forests in Nagarkot (0.18-0.28%; Juwa 1987), in Namchi, Sikkim (0.57%; Gangopadhayaya et al. 1992) and in the Royal Chitwan National Park (0.13%; Sigdel 1994). The fact that the nitrogen content in the soil was relatively low (according to the soil fertility rating system developed by NARC, 1998/1999) was probably due to the dominance of *S. robusta*. According to Bhatnagar (1965), there is low nitrogen content in good sal dominant and regeneration areas. In the floodplains, sandy loam soil is deficient in nitrogen (Sah 1997). The low nitrogen content in soil at our study site may have been due to the continuous losses through leaching and run-off (Allen 1964).

Our two study forests had high phosphorus ratings, according to the soil fertility rating system, NARC (1998/99). The soil in the pure *S. robusta* forest had higher phosphorus content than that in the mixed *S. robusta* forest; higher than the 22.59-44.28 kg/ha reported in the Riyale forest (Shrestha 1996), and higher than the 3-4 kg/ha in the Nagarkot forest (Juwa 1987). However, it was very close to the value reported for the Chitrepani forest (Shrestha 1997). It was coincided with the findings of Bhatnagar (1965).

Potassium content was higher in the pure *S. robusta* forest than in the mixed *S. robusta* forest. The value varied from 233.86 kg/ha to 267.73 kg/ha. According to Bhatnagar (1965), potassium in soil is higher in good sal regeneration areas. The sites of the present study had a higher rate of regeneration of sal, probably due to the presence of higher proportion of potassium. The value was within the range of 86.40-262.8 kg/ha as reported in *S. robusta* forest in Chitrepani (Shrestha 1997), but less than that (329.57-399 kg/ha) reported in Koshi Tappu Wildlife Reserve (Karki 1999) and higher than the value (41.01-87.79 kg/ha) reported in two sal forests in the hills of Kavreplanchowk (Pant 1997).

The forest soils in our study area contain significant quantities of all the nutrients except nitrogen. According to the soil fertility rating system of NARC (1998/99), phosphorus had a high value and potassium a medium value, while nitrogen had a low rating value. Overall, the pure *S. robusta* forest had higher soil nutrients than the mixed *S. robusta* forest, probably due to higher organic matter input from the tree cover as it had over six years' litter decomposition.

Conclusion

Soils in the forests were sandy loam. There was low nitrogen, high phosphorus and medium potassium content. Soil characteristics seem to have strong influence on the vegetation of the present study area and *vice versa*. The pure *S. robusta* forest had relatively good soil characteristics as compared to the mixed *S. robusta* forest. On the whole the nutrient-poor status of the soils found under these forests represents the degraded status of the forest. Degradation may be partly natural and partly deliberately induced by the local people for fulfilling their household needs through various strategies. Hence, the conservation of sal forests is an urgent need. The proper management of the forests will increase the quality of soils and the forest. ■

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