Changes in soil characteristics under *Shorea robusta (Sal)* stands between 1972 and 2001

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An assessment of the Sal Plot and the Fallow Plot, established about 30 years ago at Butwal, Rupandehi District, was carried out to measure the changes in the soil characteristic. Determinations were made for EC, pH, Organic carbon, total nitrogen, P, K, Na and CEC in the soil samples collected from the study plots. There were marked differences ($p<0.01$) in EC, pH and soil nutrient contents across three experimental plots. The Sal Stands had significant higher nutrient content ($p<0.01$), particularly in the surface layer, than the Fallow Plot. The increase in the soil nutrient content under Sal Stands was probably due to the presence of trees, which were consistently adding nutrients in the form of leaf litter. Of the two Sal Stands, the Stand 2 had relatively higher concentration of nutrient than the Stand 1. The rise in soil nutrient under the Sal Stand 2 was attributed to higher quantity of litter deposited due to its relatively older age.

Sal appeared to be a suitable species in the rehabilitation of the degraded sites, particularly with red soil. The fertility of forest soil can be improved through proper conservation of leaf litter and application of phosphate fertilizer where required.

Artificial plantation of *Shorea robusta* (Sal), though quite common in India and elsewhere, is a rare activity in Nepal. One such example of plantation work in this country is the Sal Stand at Lumbini Trust Development (LTD) area in Rupandehi District. The initial established of Sal in LTD was conducted in 1972 in about an acre of degraded land with the sapling prepared from the seeds collected from the Sal forest at Nawalparasi District. Following that another plantation was carried out five years later in another one-acre land adjoining to the old plot. After the early establishment, trees were allowed to grow on their own.

In April 2001 the site was revisited to see the health of the trees and site condition. The trees were found to be growing satisfactorily with good health condition. However, some differences were noted in the soil characteristics among three plots with Sal stands having relatively darker soil in the surface layer than the fallow plot.

Previous studies have shown that Sal can alter the soil properties as it grows (Pratap Narayan *et al.,* 1990; Singh *et al.*, 1985; Jha and Pande, 1984) and may have positive effect on soils leading to improvement in pH and fertility of soil (Malla, *et al.,* 2001). Amelioration of soil by the trees results largely through the supply of nutrients released from decaying leaf litter (Prasad *et al.,* 1991; Bahuguna *et al.*, 1990) and dead roots.

The present study, thus, aims to find out whether or not the visual differences observed in soil characteristics in the study plots is true and has it any relation with the presence of Sal trees as reported by others? Attempt has also been made to discuss the management implications of the findings.

Materials and Methods

Site description

Lumbini Development Trust is situated (latitude 27°28', longitude 83°17') in the Terai region, about 19 kilometers southwest of Bhairawa at an altitude of about 95 meters above sea level. The climate is subtropical, subhumid to humid. Mean annual precipitation is approximately 1700 mm with about 89 per cent of this falling in the months of June to September. Mean temperature vary from a minimum of 8°C in January to maximum of 36°C in May.

Experimental design and layout

The treatments consist of (a) Fallow Land (without trees), (b) Sal Stand-1 (planted in 1977) and (c) Sal Stand-2 (planted in 1972) laid out adjacent to each

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other in three different blocks extending from east to west. Each treatment block had seven plots of 10 x 10 m spacing placed in a systematic order.

Sample collection and analysis

A composite soil sample was taken using an auger from each 0-5 cm, 5-25 cm, 25-70 cm and 75-115 cm depths from every replicate treatment plot in the month of April. Each sample was analysed for pH, texture, organic carbon, total nitrogen, available phosphorus and exchangeable potassium following the method in Anderson and Ingram (1993).

Profile study was carried out in a 1m^3 soil pit dug in each treatment block and records were made in a standard data sheet for the colour, structure, consistency and texture of soil present in every horizon.

Statistical analysis

Analysis of variance was carried out to test the differences in the soil characteristics across the treatment plots. Comparison of soil properties of the Fallow Plot (control) with the Sal Stands was done using Least Significant Difference (LSD) test

Results and Discussion

Morphological description of soils in each experimental plot is given in Table 1. Soils were deep in nature with the depths extending over a meter. There was presence of mottle in the lower horizons in all the plots. It is an indication of the periodic water logging, particularly during the monsoon period when there is excessive rain. The number of horizons present in the profiles varied from 3 to 4. The Fallow Plot had only B horizon while the Sal Plot 1 and 2 had both A and B horizons.

Table 1. Soil profile description of the study plots.

Plot	Hor.	Depth (cm)	Description
Fallow Plot	B_{2a}	00 - 40	Loam, pale yellow 2.5 Y 7/4 (wet); few fine faint mottles; moderate coarse sub-angular blocky structure; soft friable sticky consistency; gradual boundary; abundant live root hairs present
	B_{2b}	40 - 82	Loam, strong brown 7.5YR5/6(wet); many coarse prominent mottles; moderate coarse subangular blocky structure; soft friable sticky consistency; small weathered stones; gradual boundary; few live root hairs present
	B_{2c}	82 -115	Loam, light reddish brown 2.5 YR 6/4 (wet); many coarse prominent mottles; moderate coarse subangular blocky structure; soft friable sticky consistency; small weathered stones; gradual boundry; few live root hairs present
Sal Plot 1	A_1	00 - 04	Silt loam, brown/ dark brown 10 YR 4/3 (wet); no mottle; moderate medium subangular blocky structure; soft friable sticky consistence; sharp boundry; many live root hairs present
	B_{2a}	04 - 27	Silt loam, Yellowish brown 10 YR 5/4 (wet); many coarse prominent mottles; medium coarse subangular blocky structure; hard firm sticky consistence; gradual boundry; few live root hairs present
	B_{2b}	27 - 71	Silt loam, Yellow 10 YR 7/6 (wet); many coarse prominent mottles; medium coarse subangular blocky structure; hard firm sticky consistence; gradual boundry; few live root hairs present
	B_{2c}	71 - 117	Silt loam, reddish yellow 5 YR 7/6 (wet); many coarse prominent mottles; medium coarse subangular blocky structure; hard firm sticky consistence; gradual boundry; few live root hairs present
Sal Plot 2	A_1	00 - 02	Silt loam, very dark grayish brown, 10YR 3/2 (wet); no mottle; moderate medium subangular blocky structure; soft friable sticky consistence; sharp boundry; many live root hairs present
	A_2	02 - 06	Silt loam/loam, pale brown, 10YR 6/3 (wet); few fine faint reddish brown mottle; moderate medium subangular blocky structure; soft friable sticky consistence; sharp boundry; many live root hairs present
	B_{2a}	06 - 33	Loam, reddish yellow, 7.5 YR 6/6 (wet); many coarse prominent mottle; medium coarse subangular blocky structure; hard firm sticky consistence; gradual boundry; few live root hair present
	B_{2b}	33 - 115	Loam, yellow, 10 YR 7/6 (wet); many coarse prominent mottle; medium coarse subangular blocky structure; soft friable sticky consistence; few live root hair present

The Sal Plot 1 had A1 horizon in the top and was successively followed by $B_{2(a)}$, $B_{2(b)}$ and $B_{2(c)}$ horizons. By contrast the Sal Plot 2 had two A horizons and two B_2 horizons. Distribution of live root hairs was mostly confined in the surface layer but some of it was also found in other horizons suggesting soil suitability for root growth.

Soils under the Sal Stands appeared to be more developed with distinct A and B horizons than the Fallow Plot. Development of A horizon in those plots can be attributed to the presence of trees, which had been regularly supplying organic matter in the form of leaf litter. The Stand 2 with two A and two B-horizons seems to be far more developed among three treatment plots. The variation in the soil development between two Sal Stands was possibly due to the difference in the age of the stands. The Sal Stand 2, which was older than the Stand 1, had accumulated more leaf litter over the time forming two A horizon (Prasad *et al.*, 1985). Lack of such soil development in the Fallow Plot may be related to complete absence of such trees. Similar soil development pattern was observed in studies carried out separately at Panchkhal under regenerating Sal trees (Malla *et al.*, 2001) and Dargeeling Forest Division (Singh *et al.*, 1985).

Table 2. Analytical results of soil samples collected from the experimental plots

Soil characteristic	Soil Depth (cm)	Treatments (with LSD-test)			F-test
		Fallow (n=7)	Sal I (n=7)	Sal II (n=7)	
EC (mS)	1	0.018	0.027^{c}	0.027^{c}	***
	2	0.016	0.015	0.014	NS
	3	0.010	0.011	0.010	NS
	4	0.011	0.010	0.011	NS
pH	1	5.80	5.86^{b}	6.11^{c}	**
	2	5.85	5.65^{-c}	5.92^{c}	***
	3	5.93	5.76^{-c}	5.95^{a}	***
	4	5.98	5.88^{-c}	6.05^{c}	***
Texture	1	L	SiL	SiL	
	2	L	SiL	SiL	
	3	L	SiL	L	
	4	L	SiL	L	
Exch. K+	1	0.09	0.16^{c}	0.20^{c}	***
(me)	2	0.07	0.09^{a}	0.11^{c}	***
	3	0.08	0.09	0.12	NS
	4	0.07	0.12^{c}	0.08^{a}	***
Exch. Na+	1	0.06	0.10^{c}	0.10^{c}	***
(me)	2	0.05	0.10^{c}	0.05^{NS}	***
	3	0.05	0.05	0.05	NS
	4	0.05	0.10^{c}	0.05^{NS}	***
CEC	1	3.00	4.29^{c}	6.62^{c}	***
(me)	2	2.14	2.73^{c}	2.34^{c}	***
	3	5.26	3.12^{-c}	2.92^{-c}	***
	4	3.90	4.87^{c}	3.70^{-c}	***
Available P	1	4	8^{c}	15^{c}	***
(ppm)	2	3	3^{NS}	5^{c}	***
	3	0.1	1^{c}	2^{c}	***
	4	0.1	0^{NS}	1^{b}	*
Organic Carbon	1	0.7	1.1^{c}	2.3^{c}	***
(%)	2	0.6	0.6^{NS}	0.8^{c}	***
	3	0.4	0.2	0.3	NS
	4	0.2	0.1^{-b}	0.1^{-c}	***
Total Nitrogen	1	0.12	0.15^{a}	0.22^{c}	***
(%)	2	0.11	0.13^{a}	0.10^{NS}	*
	3	0.10	0.10	0.09	NS
	4	0.07	0.09	0.08	NS

* Significant at 5% level; ** Significant at 1% level; ***Significant at < 1% level; ^{NS} Non-significant

^{a} Significant at 5% level; ^{b} Significant at 1% level; ^{c} Significant at <0.1% level; ^{NS} Non-significant

Table 2 shows the mean value of the analytical results of the soil samples collected from the study plots. Soils, in general, were medium textured with texture ranging from loam to silt loam. The Fallow Plot had loamy soil in the entire profile where as the Sal Plot-1 had only silt loam soil. In contrast the Sal Plot-2 had both silt loam and loamy soil. The upper two horizons of this plot had silt loam while the lower two had loamy soil only. The difference in the soil texture among the plots appears to have occurred during the formation of this site and does not seem to be related at all with the effect of trees.

Electrical conductivity in the experimental plots varied from 0.010 to 0.027 mS and showed gradual decline down the depth in all the plots. Soils of the Sal Plot-1 and Sal Plot-2, with similar EC value, had the highest EC (0.027 mS) in the top layer while the Fallow Plot had the lowest (0.018 mS). There was a marked variation (p<0.01) in electrical conductivity across the plots in the 0-5 cm depth. EC of both the Sal Plots (0-5 cm) were also significantly different (p<0.01) from the Fallow Plot. While the conductivity in other depths across the plots remained insignificant. EC showed strong correlation with soil depth (r = -0.79; p< 0.00) and organic carbon content (r = 0.91; p < 0.00) while its relation with pH remained insignificant. The higher EC value in the surface layers of the Sal Stands seems to be due to accumulation of soluble salt released from the leaf litter after the decomposition. Gradual decline in the EC value in the successive layer is perhaps due to limited leaching of soluble salts from the surface layer.

Soils were invariably acidic in nature with pH ranging from 5.65 to 6.11. Soil reaction across the plots varied noticeably (p<0.05 to 0.01) with the Sal Plot 2 having significantly higher pH (p<0.01) in comparison to other plots. The highest pH was observed in the Sal Plot 2 while the lowest pH was found in the Sal Plot 1. Dimri *et al.* (1987) in separate study also found similar rise in pH in the surface layer in some young Sal plantation stands. It, however, differs from the findings of Singh *et al* (1985), which shows reduction in pH in A horizon. Soil reaction showed good correlation with CEC (r=0.68; p<0.01), exchangeable K (r= 0.57; p<0.01)) and Na (r=0.52; p<0.01) but had no relation with organic carbon and soil depth (Table 3).

From the results it appears that in the initial stage when the plots were completely barren pH had the similar trend i.e. soil reaction gradually increased downwards, in all the plots. Low pH in surface layer was probably caused by the regular leaching of the basic cations such as Ca^+ Mg^+, K^+ and Na^+ from the upper layer down the profile during the rain. And, the exchange sites were replaced by H^+ ions generated from the carbonic acid (H_2Co_3) formed in water by dissolved carbon dioxide (Miller and Donahue, 1997). The above pH trend in the Fallow Plot continued, as it was barren even during the second visit of the site. However, in the other two plots the previous pH trend appears to have changed with the establishment of the Sal stands. The rise in the pH in the upper layer in the two Sal Plots seems to be caused by the incorporation of the basic cations released from the organic matter after decomposition. These cations, Ca and Mg in particular, may have replaced the H^+ and $Al(OH)_2^+$ ions, responsible for lowering of pH, resulting into increase in pH (Nugroho, 1997; Schlatter and Otero, 1995). But beneath the surface layer of the Sal Plots the trend remained much the same as the basic cations released from the litter was not leached out sufficiently in the lower layer to be able to change the pH.

Soil reaction in the all the layers of Sal Stand 2 was significantly different (p<0.01) from the Fallow Plot. This is possibly due to the presence of high

Table 3. Correlation matrix for soil properties versus organic carbon and soil depth

Soil properties	Soil depth (cm)		pH		Organic carbon (%)	
	r	*p*	r	*p*	r	*P*
EC	-0.79	0.00	0.23	0.15	0.91	0.00
pH	0.29	0.07	1.00	0.00	0.38	0.01
Org. C (%)	-0.75	0.00	0.38	0.01	1.00	0.00
Total N (%)	-0.71	0.00	0.32	0.04	0.93	0.00
Available P (ppm)	-0.73	0.00	0.42	0.00	0.98	0.00
Exch. Na (me/100 g)	-0.51	0.00	0.52	0.00	0.84	0.00
Exch. K (me/100 g)	-0.54	0.00	0.57	0.00	0.87	0.00
CEC (me/100 g)	-0.09	0.57	0.67	0.00	0.59	0.00

concentration of cations in that plot. The lower pH value of the Sal Stand 1, except in the surface layer which is also markedly different ($p< 0.01$), in comparison to the Fallow Plot appear to be related with the relatively higher leaching of cations while it was in the degraded state.

Content of total organic carbon (C), nitrogen (N) and available phosphorus (P) were highest in the upper horizon in all the plots and gradually decreased with the rise in the soil depth. There was a significant difference in the content of these nutrients and organic carbon ($p < 0.01$) (Table 2) across the plot in the upper two horizons. The Sal Stands had the highest concentration of these nutrients over the Fallow Plot. Lower content of C, N and P in the Fallow Plot can be attributed to the lack of trees and regular nutrient losses through surface erosion. The Sal Stands 1 and 2 varied significantly ($p <0.001$) with the Fallow Plot in the amount of C, N and P they possessed in the top two layer. This agrees with the findings of Malla *et al* (2001); Hosur and Dasong, (1995); Kumar *et al* (1994); Dimri, *et al* (1987) and Jha *et al* (1984), however, it differs from Nath *et al.,* (1988) who did not find any change in the soil characteristic even after 34 years. By contrast the lower two layers were inconsistent in their nutrient contents, with P showing significant difference while C and N were without any variation.

Total organic carbon, N and P contents in all the plots showed strong inverse correlation with soil depth and positive relation with each other and other nutrients but failed to show any correlation with pH. (Table 2). Singh *et al.,* (1985) and Jha *et al.* (1984) have also separately report negative relation of organic carbon with soil depth. Others (Singh *et al.,* 1985) have also reported similar positive correlation of organic carbon with soil nutrients.

Like other nutrients, the contents of exchangeable cations (Na^+ and K^+) and cation exchange capacity (CEC) were highest in the upper layer and decreased in the lower layer but with no regular trend. The content of the cations and CEC in the first two layers among the plots differed markedly. While in the lower layers variation of cations in third layer was insignificant but bottom layer was still significant. In case of CEC variation in lower layers across the plot was significant. The Sal Stand 1 and 2 had noticeably higher CEC, K and Na than the Fallow plot ($p<0.01$) in the top two layers. While in the other layers variation in Na^+ and K^+ content was insignificant. But interestingly CEC of the Sal Plots was significantly lower ($p<0.01$)than the Fallow Plot in the bottom two layers. Na, K and CEC showed strong positive correlation with organic carbon and pH (Table 3). The correlation of depth with exchangeable cations was negative while with CEC it was poor. Poor relation of CEC with depth and irregularities in the distribution of the cations can be linked with the release of basic cations from the parent material in the lower layer.

Conclusion

Shorea robusta appeared to be a suitable species in the rehabilitation of the degraded sites, particularly with red soil and can have marked effect ($p<0.01$) on soil characteristics that may vary with age of the stand.

The Sal Stands had significant higher ($p<0.01$) EC, pH, Organic carbon, total nitrogen, exchangeable cations, available phosphorus and cation exchange capacity content, particularly in the surface layer, than the Fallow Plot. The increase in soil nutrient content under Sal Stands was possibly due to the presence of trees, which were regularly adding nutrients in the form of leaf litter. Of the two Sal Stands, the Stand 2 had higher nutrient content in comparison to the other Stand. The rise in soil nutrient under the Sal Stand 2 can be attributed to higher quantity of litter deposited due to its relatively older age.

Management implications

With the decline in the natural forest resources worldwide, the plantation forestry has emerged in the recent past as an important alternative source for the supply of the forest products (Waggner, 2000). Challenges lie on minimizing the existing gap between ever increasing demand and shrinking forest product supply. To be able to overcome this problem it may require innovations not only in the technology but also in the management system. The present study, although not designed for any such innovation work, its findings may have some implications in the forest management.

Plantation and silviculture of *Shorea robusta* is no more a new technique, however, establishment of Sal Stand at LTD area is additional evidence in support of its suitability for the rehabilitation of the degraded sites in Nepal (Baral et al., 1999). Moreover it is also a confirmation for its ability to enrich the impoverished soils. But Sal's long rotation period and its ownership problem seem to be the main stumbling block in attracting the farmers in Nepal to plant this species in their farmland. Farmer's reluctance to plant Sal may also be due to their preference for fast growing multipurpose species. Despite these constraints, Sal can still be an appropriate species for plantation in the community and government land for quality timber production, which can generate ample employment opportunities and revenue.

Leaf litter is a valuable means by which trees improve the fertility of the soil supporting it. Besides several other studies, which have advocated the positive role of tree in the soil improvement, the current research is also an example in support of it. Although Oli and Manandhar (2002) have reported that litter removal in a controlled way does not affect the soil fertility, other studies have shown that continuous removal of litter in the long run can depress the yield. Intensive forest management such as whole tree harvest and forest floor sweeping can be even more detrimental to the site productivity (Melkani *et al.*, 1998; Smith, 1994; Schmidt *et al.,* 1993), as large quantities of nutrients are lost from the system along with the removal of leaf litter. Leaf litter conservation, which costs nothing but simple protection, thus appears to be the cheapest and best way by which fertility and the productivity of a forest can be sustained to the large extent (Evans, 2000) and should be given due consideration.

Unlike in most plantation sites where decrease in pH is quite common feature, interestingly in the current study an increase in soil pH in the upper layer was observed. The reported reduction in soil pH under plantation stands have been mostly the case of old stands (Billett *et al.,* 1990; Anderson, 1987; Dimri *et al.,* 1987; Banerjee *et al.,* 1986; Singh *et al.,* 1987) that have large accumulation of leaf litter (Schlatter and Otero, 1995). Insufficient foliar and soil nutrient content, appears to be the cause for the release of organic acids (Pritchett, 1979) that leads to decline in pH. While in the younger stands that have relatively thinly distributed leaf litter nitrogen and phosphorus content may be sufficient for the micro-organism to be able to decompose it without forming any organic acid (Dimri *et al.,* 1987). Moreover, the basic cations released from the litter also improve the soil pH. Thus in old stand, particularly with low phosphorus content, the decomposition of the leaf litter that have been accumulated in excess can thus be improved through application of phosphate fertilizer (O'-Connell, 1994), and can be regulated in favour of the improvement of the soil pH and nutrient availability. Further research in this topic would be highly desirable to be able to confirm it.

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