Amelioration of degraded forest soil by regenerated trees in a community forest at Kabhrepalanchok District, Nepal

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An assessment of the site and soil characteristics was carried out in three experimental plots, at Bokse Community Forest, Panchkhal. The soil properties were found to vary significantly across the plots. The Degraded Plot with heavy texture and high bulk density had very low nutrient content while the Plantation Plot with quite similar physical characteristic had slightly higher nutrient concentration. The Regeneration Plot, in contrast, had better physical-chemical characteristic than others.

Enumeration of all the tree species present in each experimental plot were also made. The Regeneration Plot had the highest tree density while the other two plots had relatively lower densities.

The improvement in soil properties in the Regeneration Plot appears to be partly due to reduction in the loss of top soil and partly due to the increased supply of nutrients in the form of leaf litter and root biomass from the large number of regenerating trees. The lack of similar changes in the soil characteristics in the other two plots can be attributed to the heavy loss of top soil through erosion and insufficient cycling of nutrients from the low tree population.

Keywords: soil amelioration, forest regeneration, community forest, Nepal.

Trees play an important role in the amelioration of soils under forestry and agricultural land use systems through the regular supply of organic matter and essential nutrients released from decomposed leaf and root biomass (Kanmegne, *et al.*, 1999; Samuzzaman, *et al.*, 1999; Rhoades, 1997; Nyberg and Hogberg, 1995; Gill and Abrol, 1986). The fine root hairs of the trees protect soil from erosion and reduce leaching of nutrients from the surface layer (Buresh and Tian, 1998).

Forest trees are felled annually in a huge number to satisfy the various needs of ever increasing human and animal populations. A recent study has revealed that in the middle mountains of Nepal about 2.3 % of forest areas are lost every year (DFRS/FRISP, 1999). As a result the forest and land resources have been heavily degraded and biomass is in increasingly short supply.

Land degradation, like in many parts of world, has become a serious problem in the middle mountains of Nepal (Shakya *et al.*, 1995). It is estimated (Carson, 1987) that about 255 tonnes of soil can be lost every year from one hectare of degraded scrub forest alone. Most of the degradation in this region occurs as a result of over-exploitation of the forest (Burton, *et al.*, 1989). Attempts are being made by the government (HMG/ADB/FINNIDA, 1988; NPC, 1998) and non-government sectors to reverse this process through rehabilitation. Several GOs, NGOs and INGOs, as well as individual farmers, independently or in collaboration, are actively involved in rehabilitation work in various districts of Nepal. The successes of rehabilitation efforts through plantation are well documented (Lal, 1998; Rongsen, 1995; Karki, 1991). The degraded forest land has also been reclaimed by community participation through regeneration of the native species (Satish Chandra and Poffenberger, 1989). Some information on rehabilitation techniques and suitable species (Howell, 1988; Baral *et al.*, 1999) and various management options (Rongsen, 1995) for the degraded sites are available; however, little is known about the effects of rehabilitation practices on soil characteristics.

In this context, the present study aims to find out whether the differences in the site and soil characters of the degraded and non-degraded plots are due to the variation in the vegetation cover in the plots developed in rehabilitation work done in the last one and half decades.

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Methods

Site description

The present study was carried out at Bokse Community Forest, situated north of Panchkhal at an altitude of 900 m asl. It falls in block number 1 of the Bokse VDC. The climate is sub-tropical with hot summer and cold and dry winter. Average air temperatures are as high as 31.8 ° C in July and can go down to only 5.2 ° C in January. The relative humidity varies from 68% in March to 90 % in December (DHM, 1997a) with annual rain fall 1056 millimetres (DHM, 1997b). Of the total precipitation, the greatest proportion falls during the summer monsoon, that is between May and September.

The study area, heavily forested until 1930, turned into a degraded land by the early 1980's (Kharel and Regmi, 1995). The largest part of the forest was lost between 1950 and 1981 (Schreir and Shah, 1994). Efforts to rehabilitate the degraded sites made independently by the Australian Forestry Project and the Forest Survey and Research Office (Neil, 1987) had very limited success. However, the forest was cited to make a gradual improvement after it was handed over to the community people in 1993. Although a large portion of the degraded land has now been occupied by regenerating trees, degraded areas and deep gullies are still present.

Treatments

The experiment was purposely made simple by having no replication of the treatments in order to generate useful information easily in short time. The treatments consisted of three different plots: Degraded Plot, Plantation Plot and Regeneration Plot, situated about 10-20 m apart from each other. All the plots were equally degraded before they were looked after by the community people. The Degraded Plot, located east of the foot trail to Bokse village, is a highly eroded site with few scattered shrub species such as *Rhus parviflora* and *Phoenix sylvestris,* and tree species like *Pinus roxburghii* and *Shorea robusta*. There are two big gullies on either side of the plot. The Plantation Plot, relatively less eroded, is situated about 30 metres north-east of the Degraded Plot and is planted with exotic *Acacia* species a decade and half ago. The Regeneration Plot lies about 10 metres south of the fenced plot. It has many regenerated sal and other indigenous tree species. There is a large deep gully extending north-south, about 10 metres east of this plot.

Soil Sampling and analysis

A pit (1 m^3) was dug in each plot and the soil profile was examined. One soil sample from each horizon was collected for the physico-chemical analysis such as bulk density, pH, texture, organic carbon, total nitrogen, available phosphorus and exchangeable potassium. The determinations were made following the methods described by Anderson and Ingram (1993).

Vegetation analysis

A quadrat (10 x 10 metres) was used for the enumeration of the tree species present in each experimental plot. All the species lying in the quadrat were identified and recorded. The process was repeated in every plot and the species present in the plots were listed (Table 3).

Results

Table 1 gives a description of the soil profile in the three study plots. All the study plots have soils with a depth greater than one metre. The number of horizons present in the pits varies from one to three. The Degraded Plot has one continuous layer of B2 horizon while the Plantation Plot has A2 and B2 horizons. The Regeneration Plot in contrast has three distinct horizons, named as A1, A2 and B2.

The soils, except in horizons A1 and A2 of the Regeneration Plot, are heavy and poorly drained. By contrast, the first two horizons of the Regeneration Plot have light, friable and well drained soil. In all plots there is some illuvial clay deposition from upper to lower horizons that explains why the lower horizons in almost all the plots have heavier texture than the upper ones.

The analytical results of the soil samples collected from the three plots are given in the Table 2. The bulk densities of the top soils in the study plots range from 1.1 to 1.5. The Plantation Plot and Degraded Plot have higher bulk densities (1.5, 1.4) whereas the Regeneration Plot has the lowest density (1.1) and this gradually increases down the profile (1.4).

The soil reaction in three plots ranges from 4.6 to 5.5 (Table 2). The top horizons of all the plots have pH around 5.5. In the Regeneration Plot it gradually decrease below surface and again attains the pH similar to that of upper horizon. In the Plantation Plot it remains the same in both the horizons.

Table 1. Soil profile description of the study plots

Plot	Hor.	Depth	Description
Degraded Plot	B2	0-100+	Clay; red 2.5YR4/6(dry); common fine distinct N3/0 mottles; strong coarse subangular blocky structure; firm (moist) consistence; few live roots *present; vertical deep cracks observed; termite activity seen*
Plantation Plot	*A2*	*0-20*	*Clay loam; red 2.5YR4/6(dry);* common fine distinct N3/0 mottles; strong coarse subangular blocky structure; firm (moist) consistence; live roots present; ant hole and hills seen.
	B2	21-100+	Clay; red 2.5 YR3/4(dry); many fine distinct N2/0; strong coarse subangular blocky; firm (moist) consistence; live roots present; ant hole and hills seen.
Regeneration Plot	A1	0-5	Sandy Clay loam; Yellow brown 10YR5/8(dry); no mottles; moderate subangular blocky structure medium; friable (moist) consistence; sharp; few live dead roots present
	A2	6-30	Sandy Clay loam; *red 2.5YR4/6(dry);* no mottles; strong subangular blocky structure medium; friable (moist) consistence; occasional stones; clear boundary; abundant live roots present: small charcoal piece.
	B2	31-100+	Clay; red 2.5YR3/6(dry); few fine faint black; Strong subangular blocky structure coarse; friable (moist) consistence; clear boundary; abundant live roots present; small charcoal piece.

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

Soil Characteristics	Degraded Plot		Plantation Plot		Regeneration Plot			Reference* Soil
	30 cm	50 cm	30 cm	50 cm	5 cm	30 cm	50 cm	
Bulk Density	1.4		1.5		1.1	1.2	1.4	
Sand (%)	12	14	16	37	50	50	11	
Silt (%)	25	25	25	25	27	23	28	
Clay (%)	63	61	59	38	23	27	61	
Texture Class	Clay	Clay	Clay	Clay loam	Sandy clay loam	Sandy clay loam	Clay	
pH(1:2.5 H_2O)	5.35	4.63	5.47	5.46	5.40	5.04	5.48	
Exch K(me/100 g)	0.4	0.3	0.1	0.3	0.4	0.2	0.6	
Available P Bray	0.0	0.0	0.0	0.0	3.0	1.0	0.0	
Total Organic C (%)	0.1	0.1	0.5	0.3	1.9	0.8	0.4	4.6**
Total N (%)	0.05	0.05	0.05	0.07	0.16	0.08	0.08	0.36***

* ISE 95.2,2

** Carbon percentage in the reference sample reported in the book is 4.2 %

*** Nitrogen percentage in the reference sample reported in the book is 0.35 %

The contents of organic carbon, total nitrogen and available phosphorus in the three plots differ greatly. These elements are present in very low concentrations in the Degraded Plot and the Plantation Plot. While the levels of organic carbon and total nitrogen in the Regenerating Plot are medium to high in the top horizon, they gradually decrease down the profile. The available phosphorus in the Regeneration Plot, although relatively higher than other two plots, is still low. Exchangeable potassium in all three plots ranges from high to very high.

Vegetation analysis

Table 3 lists the tree density found in the research plots. The Regeneration Plot which has only *Shorea robusta*, has the highest tree density, while the Plantation plot has the second highest density with mixed tree species. The Degraded Plot has the lowest number with almost equal distribution of *Shorea robusta* and other tree species.

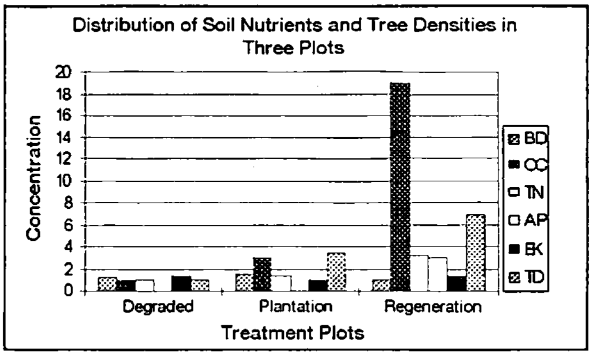
Discussion

There is a distinct variation in the vegetation cover among the three plots which were in the similar state until 1982. The density of trees in the Regeneration Plot is significantly higher than in the other plots, and this may be due to the presence of old stumps which remained there after harvest. The protection of the trees from grazing and illegal felling by the local people may have further helped it to grow properly. The occurrence of some exotic trees in the Plantation Plot is mainly due to their introduction during the rehabilitation of the plot. The lower tree density in the Degraded Plot can be attributed to the lack of either protection or plantation. Also, most of the stumps have been dug out, along with all the other tree parts, for firewood collection by the local people. This was also revealed during semi-structured discussions with people of the community. The soil characteristics appears to have little role in the regeneration as the other plots having similar condition had good regeneration. This agrees with the findings of Suoheimo (1995).

The low soil bulk density of the Regeneration Plot in the top horizon can be attributed to the presence of a high level of organic matter content in the soil and the physical ameliorative effects of the roots. The progressive increase of density down the profile may be related to a gradual decrease in the level of the organic carbon. In contrast the high bulk densities in the other two plots seem to be linked to the low content of organic carbon. The bulk density of each soil appears to correspond with the texture and level of organic carbon.

The high content of organic carbon, nitrogen and potassium in the Regeneration Plot is probably due to higher organic matter input from the tree cover. It may also be partly due to the accumulation of the top soil washed out in the surface erosion from the slope above, being trapped by the vegetation. The nutrients present in this plot are comparable to the other sal forest plot (Banerjee *et al.*, 1989 a and b). The relatively low concentration of organic carbon, nitrogen and potassium in the Plantation Plot and Degraded Plot appears to be due to the low organic input from the vegetation cover and higher surface erosion. The nutrient content of the surface layer in the three plots correlates well with the tree density in the three plots (Figure 1), indicating that the tree cover has a positive role in the amelioration of the soil.

Fig 1: Relative distribution of soil nutrients and tree density in three plots



TD = Tree Density; EK = Exchangeable Potassium; AP = Available Phosphorus; TN = Total Nitrogen; OC = Organic Carbon; BD = Bulk Density

Conclusion

The study plots at Bokse Community Forest, existing initially in a similar degraded condition, now appear to differ markedly in their site and soil characteristics after trees started regenerating. The Regenerating Plot, with good physical rooting conditions and high nutrient contents, appears to be a rich site. The other two plots, having low nutrient contents and unhealthy physical rooting conditions, can be taken as poor sites.

The variation in soil properties in the study plots appears to be closely related to their tree densities: the Regeneration Plot with its higher tree density has relatively better soil characteristics, while the other two plots with lower tree densities are poor.

Table 3. Densities of various tree species found in the experimental plots

Trees	Density (number/ha)		
	Degraded Plot	Plantation Plot	Regeneration Plot
Shorea robusta	300	100	3816
Others	250	1800	-
Total	550	1900	3816

Table 4. Relative distribution of soil nutrients and tree density (in ratio) in three plots

Treatments	Degraded Plot	Plantation Plot	Regeneration Plot
Bulk Density (BD)	1.27	1.45	1.00
Organic Carbon (OC)	1.00	3.00	19.0
Total Nitrogen (TN)	1.00	1.40	3.20
Available Phosphorus (AP)	0.00	0.00	3.00
Exchangeable Potassium (EK)	1.33	1.00	1.33
Tree Density (TD)	1.00	3.45	6.94

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