Time frame for the reclamation of degraded forest sites

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Two forest plots in Rupandehi and Kabhrepalanchok Districts were examined to assess the changes in soil characteristics under Sal (*Shorea robusta*) trees established through plantation and regeneration processes respectively. Along with studies of the soil profiles, measurements were also made for pH, organic carbon, total nitrogen, available phosphorus and exchangeable potassium in sample collected from these plots. Indicators of reclamation such as development of tree cover, formation of an A (topsoil) horizon, and rise in soil nutrient content were observed in both plantation and regeneration plots. The Plantation Plot took 30 years whereas the Regeneration Plot required only 20 years to appear substantially and sustainably reclaimed.

Keywords: Time frame, reclamation, forest degradation, Nepal

Forest degradation is a major environmental problem in Nepal with about 1.8 million ha productive woodlands already converted to degraded land (Pratap and Watson, 1994). Degradation is primarily caused by over-exploitation of forest trees carried out to fulfil the growing demands of the local people for various tree products (Ball *et al.,* 2002; Nik Mohd Majid *et al.,* 1996; Schmidt, 1991; Shakya *et al.,* 1991). Every year about 1.7 per cent of the forestland is lost (DFRS, 1999) and nearly 255 million tons of fertile soils are washed out (Carson, 1985) leading to formation of increased number of denuded lands with highly eroded and depleted soils.

Degraded forestlands can be effectively reclaimed through various methods and can successfully regain their original productivity and tree cover (Lamb and Gilmour, 2003; Gilmour *et al.* 2000; Banerjee, 1995; Moffat and McNeill, 1994). Previous efforts made in this field in Nepal consists of reclamation through natural regeneration of Sal *(Shorea robusta),* which produced positive outcomes with the development of sufficient tree cover and enriched topsoil in the degraded lands (Baral *et al.,* 1999). It is a simple and less costly method for reclamation, as regeneration rate of Sal is relatively high (Rautiainen, 1996) and the resource required is minimal. Another suitable way of reclaiming the degraded hill sites is through plantation of trees, shrubs and grasses (Singh and Vasistha, 2004; Baral, *et al.,* 2000; Rongsen, 1995; Shah, *et al.* 1995). Similarly, reclamation can also be carried out with the participation of community people and can be comparatively more productive and cost effective (Baral *et al.,* 1999, 2003; Mahto *et al.,* 1998; Rongsen, L. 1995; Shah, *et al.,* 1995; Satish Chandra and Poffenberger, 1989).

Reclamation work, being a long-term activity, requires enormous amount of resource and commitment to accomplish it successfully. In countries like Nepal, where lack of financial resources is a big constraint, such activity should be initiated only with the prior knowledge of time and resource required such that proper arrangement and planning could be made for it beforehand. Estimation of resource essential for such work, however, can easily be made through the knowledge of the time period need to achieve such work. Although previous reclamation efforts, which were mostly of small-scale, have been fulfilled without such information, a large-scale reclamation if carried out in a similar way may involve high risk of failure due to resource constraints and lack of proper planning. The knowledge of time frame, which so far seems to have been completely ignored, can be valuable for conducting rehabilitation work in a systematic and organized way and ensuring success. The present study, therefore, aims to generate such information based on available reclaimed plots established in two districts some time ago. The findings can be of great value for successful large-scale reclamation work in this country to reinstate forest to the original state.

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The article outlines the changes that occurred in soil characteristics under *Sal* trees growing in the regeneration and plantation plots established for the reclamation of the degraded sites. It also attempts to estimate the time frame for reclamation by comparing the development in the soil attributes in these sites with that of natural *Sal* forest of site classes I and II.

Material and methods

Site description

The study was carried out separately in two districts: one at Rupandehi and another at Kabhrepalanchok. The plot at Rupandehi was developed through plantation of *Sal* trees while the other plot at Kabhrepalanchok was established through regeneration of same species

Rupandehi site

This site falls in the Lumbini Development Trust Area, situated about 19 kilometres south-west of Bhairahawa at an altitude of about 95 metres above sea level. The climate is subtropical, sub-humid to humid. Mean annual precipitation is approximately 1700 mm and mean temperatures vary from a minimum of 8°C in January to maximum of 36°C in May. The site was highly eroded and barren before reclamation work was initiated. The terrain is of deep depositional material on a very gentle slope, forming part of the Terai lower outwash-alluvial plains. Soils are stratified according to localised depositional patterns, and are deep with loam to silt loam textures.

Treatments were: (a) Fallow-a Plot (b) Sal Plot Ia (planted in 1977) and (c) Sal Plot IIa (planted in 1972) laid out adjacent to each other in three different blocks extending from east to west.

Kabhrepalanchok site

The plot lies within the Bokse Community Forest, located in block number 1 of the Bokse VDC, Panchkhal. It is situated at an altitude of 900 m asl. The climate is sub-tropical with air temperatures ranging from 31.8°C in July to 5.2°C in January and the relative humidity varies from 68% to 90%. The annual rainfall is 1056 mm. The slope gradient ranges from 5-10°. It is located on an ancient and deeply weathered residual landform, characterised by deep red soils with loam to clay loam texture: these residual soils are the subject of intense weathering in humid sub-tropical conditions and have certain characteristics which resemble laterites. The site had sparsely distributed trees and was devoid of a distinct topsoil.

Treatment consists of Fallow-b Plot, Sal Plot Ib and Sal Plot IIb situated about 10-20 m apart from each other. The Fallow-b Plot was flanged by two big gullies on either side. The Sal Plot Ib was situated about 30 metres northeast of the Fallow-b Plot and was planted with exotic *Acacia*. The Sal Plot IIb was located about 10 metres south of the fenced plot. It had many regenerated Sal and other indigenous tree species.

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 treatment block. The samples were analysed for pH, texture, organic carbon, total nitrogen, available phosphorus and exchangeable potassium following the method mentioned in the manual by Anderson and Ingram (1993). A 1m^3 soil pit was also dug in each treatment block to study profile and records were made for the colour, structure, consistency and texture of soil present in every horizon in a standard data sheet.

Estimation of time frame

Time required for reclamation of any degraded site depend on several factors such as site characteristic, climate, land terrain, state of degradation, method applied, tree species used and other micro conditions. Thus an estimated time period for such activities is linked with all these factors and is applicable for those conditions only. But considering the variation present in the site characteristics even within a short distance, the estimated value, however accurately it may have been determined, may not apply in the other sites exactly as in the original site. Even with some variations the tentative value can still be highly useful in the reclamation work. In the present study the idea is to estimate time span for reclamation of degraded forest sites, initially devoid of tree cover and nutrients, situated in two different set of conditions; firstly through plantation in the plain land and secondly through regeneration in the hill region. The estimated value obtained for the Rupandehi site will represent the reclamation time for the Sal plantation process in plain land while the result achieved for the Kabhrepalanchok site will stand for the time through regeneration in the hilly areas. Indicators used for the assessment of the reclamation were tree density, soil profile and soil nutrient content.

The time frame was estimated by comparing the reclaimed plots of different age groups with natural Sal forests. The plot that had tree density, soil profile and nutrient content comparable to natural Sal forest was taken as a reclaimed site and the corresponding age was considered as reclamation time period. The natural Sal forest chosen for the comparison was of class I and II.

Results

Profile description of the study plots is given in the Table 1. The Fallow Plots in both the sites had a continuous B_2 horizon while the Sal Plot Ia and Sal Plot Ib had clear A_2 and B_2 horizons. The Sal Plot IIa at Rupandehi, and Sal Plot IIb at Kabhrepalanchok besides A_2 and B_2 horizons had an additional A_1 horizon.

Soil texture differed noticeably between the two sites and among the plots within a site. Rupandehi site had soil texture ranging from loam to silt loam whereas the Kabhrepalanchok site had clay to silt clay loam texture. Table 2 shows the properties of soil samples collected from the study plots at Rupandehi and Kabhrepalanchok Districts. Soil pH recorded in two sites were of acidic character and ranged from 4.63 to 6.11.

The highest pH (6.11) was observed in the surface layer in the Sal Plot II of the Rupandehi site while the lowest pH (4.63) was in the third layer (25-70 cm) of the Fallow-b-Plots in the Kabhrepalanchok Site.

The Fallow-Plot had the lowest soil reaction in the upper layer and it gradually increased in the successive lower layers. The Sal Plots did not show any such trend instead it had higher pH in surface layer, which decreased in the second layer, but it further increased in the following layer. The upper layer of the Sal Plot in both the sites had relatively higher pH than the Fallow-Plot.

Table 1. Soil profile description of the study plots at Kabhrepalanchok and Rupandehi Districts

Site	Plot	Hor.	Depth (cm)	Description
Rupandehi	Fallow-a	B_{2a}	00 - 40	Loam, pale yellow 2.5 Y 7/4; few mottles; sub -angular blocky structure; soft friable consistency; gradual boundary; abundant live root hairs
		B_{2b}	40 - 82	Loam, strong brown 7.5YR5/6; many mottles; sub -angular blocky structure; soft friable consistency; small stones; gradual boundary; few live root hairs
		B_{2c}	82 -115	Loam, light reddish brown 2.5 YR 6/4; many mottles; sub -angular blocky structure; soft friable consistency; small stones; gradual boundary; root hairs
	Sal 1a	A_2	00 - 04	Silt loam, brown/ dark brown 10 YR 4/3; no mottle; sub -angular blocky structure; soft friable consistence; sharp boundary; many live root hairs
		B_{2a}	04 - 27	Silt loam, Yellowish brown 10 YR 5/4; many mottles; sub -angular blocky structure; hard firm consistence; gradual boundary; few live root hairs
		B_{2b}	27 - 71	Silt loam, Yellow 10 YR 7/6; many mottles; sub -angular blocky structure; hard firm consistence; gradual boundary; few live root hairs
		B_{2c}	71 - 117	Silt loam, reddish yellow 5 YR 7/6; many mottles; sub -angular blocky structure; hard firm consistence; gr adual boundary; few live root hairs
	Sal IIa	A_1	00 - 02	Silt loam, very dark greyish brown, 10YR 3/2; no mottle; sub -angular blocky structure; soft friable consistence; sharp boundary; many live root hair
		A_2	02 - 06	Silt loam/loam, pale brown, 10YR 6/3; few mottle; sub -angular blocky structure; soft friable consistence; sharp boundary; many live root hairs
		B_{2a}	06 - 33	Loam, reddish yellow, 7.5 YR 6/6; many mottle; sub -angular blocky structure; hard firm consistenc e; gradual boundary; few live root hair
		B_{2b}	33 - 115	Loam, yellow, 10 YR 7/6; many mottle; sub -angular blocky structure; soft friable consistence; few live root hair
Kabhrepal anchok	Fallow-b	B_2	0-100+	Clay; red 2.5YR4/6; distinct mottles; sub -angular blocky structure; firm consistence; few live roots
	Sal Ib	A_2	0-20	Clay loam; red 2.5YR4/6; distinct mottles; sub -angular blocky structure; firm consistence; few live roots
		B_2	21-100+	Clay; red 2.5 YR3/4; many distinct mottles; sub -angular blocky; firm consistence; few live roots
	Sal IIb	A_1	0-5	Sandy Clay loam; Yellow brown 10YR5/8; no mottles; sub -angular blocky structure; friable consistence; sharp; few live roots
		A_2	5-30	Sandy Clay loam; red 2.5YR4/6; no mottles; sub -angular blocky structure; friable consistence; few stones; clear boundary; abundant live roots.
		B_2	30-100+	Clay; red 2.5YR3/6; few mottles; sub -angular blocky structure; friable consistence; clear boundary; abundant live roots

Table 2. Soil analytical results of the study plots and reference natural Sal forest (NSF)

Soil Properties	Depth (cm)	Rupandehi			Kabhrepalanchok			Reference*	
		Fallow-a 20 year	Sal Ia 15 years	Sal IIa 20 years	Fallow-b 15 years	Sal Ib 15 years	Sal IIb 15 years	NSF SC 1	NSF SC 1.86
Horizon	0-5	B_{2a}	A_2	A_1	B_2	A_2	A_1	A_1	A_1
	5-25	B_{2a}	B_{2a}	A_2+ B_{2a}	B_2	A_2	A_2	A_1	A_1
	25-70	B_{2a} +B_{2b}	B_{2b}	B_{2a}	B_2	B_2	B_2	B_2	A_1+ B_2
pH	0-5	5.80	5.86	6.11			5.40		
	5-25	5.85	5.65	5.92	5.35	5.47	5.04	6.2	6.2
	25-70	5.93	5.76	5.95	4.63	5.46	5.48	6.2	5.8
Exch. K+	0-5	0.09	0.16	0.20			0.4		
(me)	5-25	0.07	0.09	0.11	0.4	0.1	0.2	0.62	0.24
	25-70	0.08	0.09	0.12	0.3	0.3	0.6	0.63	0.23
Available P	0-5	4	8	15			3.0		
(ppm)	5-25	3	3	5	0.0	0.0	1.0		
	25-70	0.1	1	2	0.0	0.0	0.0		
Organic C	0-5	0.7	1.1	2.3			1.9		
(%)	5-25	0.6	0.6	0.8	0.1	0.5	0.8	2.4-2.7	1.79
	25-70	0.4	0.2	0.3	0.1	0.3	0.4	0.31	0.78
Total N	0-5	0.12	0.15	0.22			0.16		
(%)	5-25	0.11	0.13	0.10	0.05	0.05	0.08		
	25-70	0.10	0.10	0.09	0.05	0.07	0.08		

* Source: Sharma *et al.* 1985, SC= Site Class

Total nitrogen, available phosphorus, exchangeable potassium and total organic carbon contents were comparatively higher in the Sal plots than in the Fallow-Plot in both the experimental sites. The amount of organic carbon in the two sites ranged from 0.1 to 2.3 per cent with the Sal Plot IIa of the Rupandehi site having the highest whereas the Fallow-Plot of the Kabhrepalanchok site had the lowest content in the bottom layer. In all the plots the surface layer had higher content of organic carbon, which gradually decreased in the successive layers. Distribution of nitrogen and available phosphorus along the profile showed similar trend with the highest concentration in the top layer and the lowest in the bottom layer. The Sal IIa plot of the Rupandehi site had the highest content (N=0.22 %; P=15 ppm) while the third layer of the Fallow-Plot of the Kabhrepalanchok site had the lowest (N=0.05 %; P= traces). Distribution of exchangeable potassium, unlike other nutrients, did not show any clear trend along the profile. The highest concentration of K (0.6 me) was present in the bottom layer of Sal IIa plot of the Kabhrepalanchok site while the lowest K (0.08 me) content was in the third layer of Fallow-Plot.

Table 2 gives the comparative results obtained from present study and from the study conducted by Sharma *et al.* 1985. The Sal Plot IIa at Rupandehi and the Sal Plot IIb at Kabhrepalanchok aged 30 and 20 respectively compared well with profile and soil properties of the natural Sal forest showing that these plots were reclaimed. While the other two plots viz. Sal Ia and Sal Ib failed to attain the value suggested.

Discussion

The reclaimed plots, which were in a highly degraded state initially, appear to have recovered quite well after the growth of *Shorea robusta* established through plantation at Rupandehi and natural regeneration at Kabhrepalanchok. Development of A horizon and increment in soil nutrient content in the surface layer of these plots, seem to be linked with the presence of the trees that constantly supplied organic matter in the form of leaf litters and dead roots. This may also be partly due to the reduction in soil run off loss affected by the root hairs distributed in the surface layer (Ries, 1991; Mathema and Singh, 2003). Dimri (1987) and Jha *et al.* (1999) have independently reported similar positive effects of Sal trees on soil nutrient status. The difference in nutrient contents between the Sal Plot Ia and Sal Plot IIa at the Rupandehi Plot were also quite distinct with the former having a lower nutrient content than the latter. This can be attributed to relatively larger quantity of leaf litter accumulation in the older plot. This agrees well with the findings of Dimri *et al.,* (1987) and Banerjee *et al.,* 1989(a) and 1989(b) who have also reported higher nutrient content in the older *Sal* stands. Variation in the nutrient content was also observed between the Sal Ib and Sal IIb Plots at Kabhrepalanchok site. Although plantation in the

Sal Plot Ib was initiated at nearly the same time, it has relatively lower nutrient concentration than the Sal Plot IIb. This seems to be linked to the higher tree density in the Sal Plot IIb (Malla *et al.*, 2001). This resembles with the findings of Banerjee *et al.*, 1989(a) and 1989(b).

The development of A (topsoil) horizons and enrichment in soil nutrients under the reclaimed stands appear also to be related with the age of the stands, indicating that a certain time frame is required to attain a given level of changes in soil properties. It is important to see this in the context of differences in both sites and treatments: Rupandehi has relatively light soils and trees were restored by plantation, whereas Kabhrepalanchok has heavier soils and forest restoration came about through regeneration from relict root stock. Despite these limitations, and the clearly different depth of A (topsoil) horizon formation between the Sal Plots in the two sites (see Table 1), nutrient status variations are key indicators and the study results provide a basis to estimate the time length for changes to take place. The fallow plots at both sites represent an approximate control, in terms of the stage of degradation that had occurred due to heavy exploitation of the forests. Until 1950 the experimental plots in both the districts were heavily forested but by the early 1980s both areas had been reduced to degraded land (Kharel and Regmi, 1995). Following protection and plantation, the slow process of reclamation has reversed degradation.

Trees in the Sal Plot Ia and Ib were established about fifteen and twenty-five years before the study was made, and there are signs of topsoil amelioration starting. However, these plots still have quite a way to go before reaching values near to natural Sal forest (Sharma *et al.* 1985); but soil amelioration might be expected to speed up once canopy closure has been achieved.

The Sal Plot IIa at the Rupandehi site, aged thirty years, appears to resemble natural Sal forest (Sharma *et al.* 1985) in profile characteristics and nutrient content, while the Sal Plot Ia, which is 5 years younger with similar tree density, seems to have nutrients less than reference values (Table 2). Thus, a degraded site located in the Terai, and with a tree density around 1800-2000/ha given no additional management inputs, may require about thirty years for the reclamation of degraded soil.

Likewise, the Sal Plot IIb at the Kabhrepalanchok site, though 10 years younger than the Sal Plot IIa at Rupandehi, also seems to match with the soil characteristics of natural forest, suggesting that the site has been effectively reclaimed. Despite its younger age the rise in nutrient levels to the expected range in Sal Plot IIa is probably due to the higher tree density of 3816/ha (Baral *et al.*, 1999), which increased the nutrient accumulation rate. This site, located in the hills, may require a relatively high tree density to achieve a nutrient level similar to that of the plain land in a given time, as the former is likely to have higher nutrient losses through surface run off during excessive rain.

In contrast the Sal Plot Ib (Kabhrepalanchok), which was established at almost the same time as the Sal

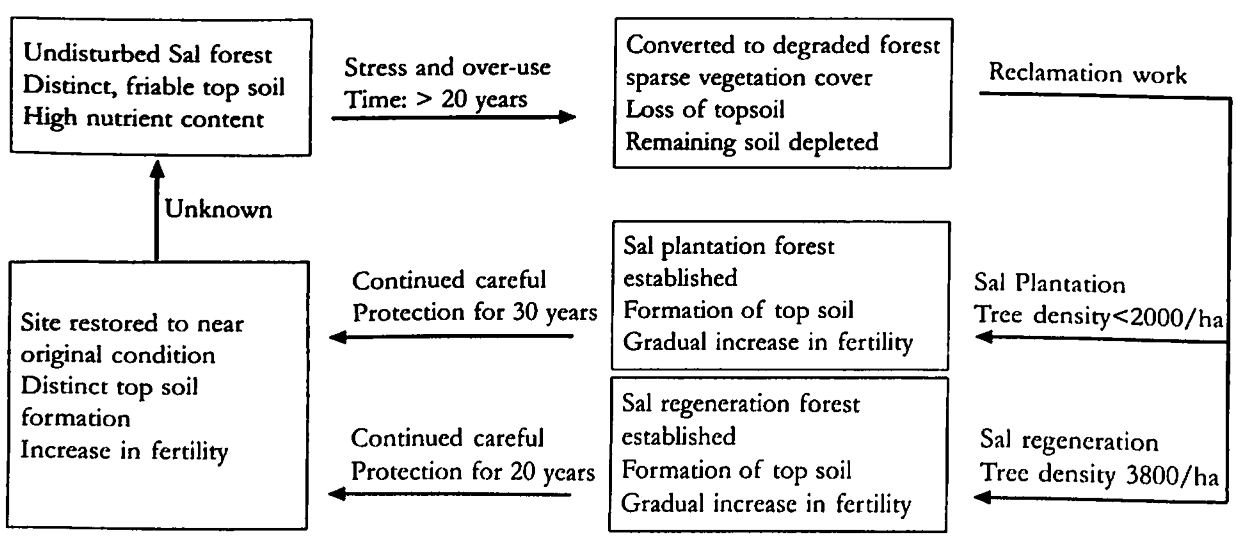

Fig 1. Flow chart showing the process and time involved in the reclamation of degraded forest sites

Plot IIa (Rupandehi), had far less nutrients than the reference values, indicating that 15 years is insufficient for reclamation with a tree density of about 1.600-2000/ha. Although this plot resembles Sal Plot IIa of Rupandehi in its tree density, it fails to gain the given nutrient value, probably due its lower age and different site characteristics.

Information obtained from the present study allows us to develop a tentative model for the time involved in the reclamation of degraded sites through both plantation and natural regeneration (Figure 1).

Conclusion

Degraded forestland can be reclaimed effectively with sufficient tree density, development of A horizon and increase in soil nutrient content, both through plantation as well as regeneration of *Shorea robusta.* Development of profile and enrichment of soil in the reclaimed plots appear to relate positively with age and density of the tree in the forest stand. Terrain characteristics may also have some effect on reclamation if the age and density of tree cover remain constant.

The length of time required in the two processes to reclaim to a given level, however, was found to vary markedly with natural regeneration requiring only 20 years, while a plantation needs 30 years.

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