Natural regeneration potential and growth of degraded *Shorea robusta* Gaert n.f. forest in Terai region of Nepal

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Sal *(Shorea robusta)* has ecological, economical and socio-cultural importance. It is a dominant species in the Terai and Chure region of Nepal. Natural regeneration is the only relevant regeneration method for Sal in Nepal. This study intended to assess natural regeneration potential of Sal in ploughed and unploughed (control) sites. The study was carried out in Chetaradei of Kapilvastu district in an area of 4.79 ha. Two treatments (control and ground work *i.e*. ploughed) were applied to assess regeneration potential of Sal. The radius of the sample plots was 2 m, which were laid out systematically and the data were recorded from these plots in three consecutive years. Regeneration density was found higher in control site than ploughed site. T-test for regeneration density in three consecutive measurements showed that there was no significant difference between ploughed and unploughed conditions. The species composition was dominated by Sal in both ploughed and unploughed sites. Species diversity (Shannon Weiner) index was found higher in ploughed site than unploughed site in three consecutive measurements. Moreover, T-test showed that mean height of Sal was not significant in both ploughed and unploughed sites except in the first measurement. This study shows that protection from grazing and fire is essential for natural regeneration of Sal. However, ground work helps to increase tree species diversity but it is not necessary in degraded Sal forest.

Keywords: Ground work, Kapilvastu, plough, treatment

Sal (*Shorea robusta*) forest is one of the 35 different forest types found in Nepal (Stainton, 1972). It is a dominant species, shares 54.77% and 48.64% of the total stem volume in Terai (DFRS, 2014a) and Chure (DFRS, 2014b) regions, respectively. It is mainly valued for strong and durable construction timber but used as fuel and fodder as well (Jackson, 1994). Multiple product management for Sal is essential from social, economical and ecological perspective (Gautam and Devoe, 2006).

Natural regeneration is the only relevant regeneration method for Sal in Nepal (Joshi *et. al*., 1995). Although many known and unknown causative factors affect the process of natural regeneration, the major factors include climate, soil, seed, biotic conditions, etc. (Singh *et al.*, 1987); and soil moisture and light intensity (Tyagi *et al*., 2011). However, Sal forests in Nepal are shrinking with poor regeneration and there is change in species composition as well (Sapkota *et al*., 2009) which is a challenge for Sal forest management.

Variation in species composition, regeneration status and diversity in Sal forest is determined by altitude, climate and edaphic factor (Uma, 2001). In order to know the regeneration potential of Sal in degraded Sal forest, studies have been conducted in different parts of the country. However, these studies are limited to assess regeneration potential and growth of Sal only under different thinning regimes in different forests system (high forest, coppice forest) without ground work (*i.e.* exposure of soil). Soil working facilitates seed to grow due to easy aeration and nutrient uptake as compared to a compact soil. Soil compaction typically decreases absorption of major mineral nutrients, especially N, P and K by roots (Kang and Lal, 1981) resulting in growth inhibition such as parks and golf courses (Davis, 1952; Lunt,

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1956) and timber harvesting areas (Youngberg, 1959, Sands and Bowen, 1978).

In this regard, this study was carried out to assess regeneration potential and growth of Sal forest in ploughed and unploughed sites in Terai region, which is different from previous studies. Thus, the study intended to know the effect of exposure of soil in natural regeneration potential and growth of Sal.

Materials and methods

Study area

The study was carried out in Tilaurakot collaborative forest. It lies in Chetaradei of Kapilvastu district (Fig. 1), approximately 15 km to the south of the Mahendra Highway near to Gorusinghe bazaar. The study site was established in 2013.

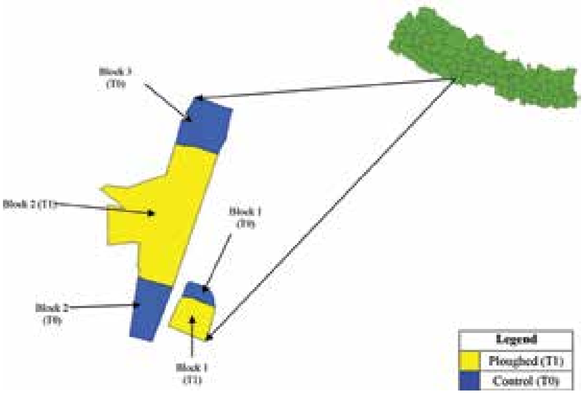


Fig. 1: Map of the study area with allocation of treatments in Kapilvastu district

Condition of the study area

The whole site was clear felled except maintaining few mother trees to promote regeneration. Dispersal of seeds from the mother trees was enough to cover the extent of the study area as seeds disperse approximately 100 m away by wind (Jackson, 1994). Before the treatments applied, the site was absence of Sal regeneration. It was supposed to be very difficult to regenerate Sal without any intervention. Thus, the site was ploughed using Tractor assuming that there would be regeneration. The whole site was fenced and guarded to protect Sal regeneration from grazing and fire.

Research design

Ploughing was done in two blocks of the selected site whereas three blocks of the site were treated as control (Fig. 1). The detail of the research design is given in table 1.

Circular sample plots had 2 m radius and were spaced systematically. Spacing between the plots was 30m x 30 m for ploughed site and 20m x 20m for unploughed (control) site. Altogether, 50 and 41 sample plots were employed in ploughed and unploughed sites, respectively (Table 1).

Data collection

For the study, regeneration of Sal includes both seedling (height <1m) and sapling (height>1m and dbh<10 cm). Recorded variables were species, its frequency and height. The first data collection was carried out after three years of establishment of the research plots and continued for another two years.

Data analysis

The data analyses included estimation of regeneration/ha, mean height, species diversity in ploughed and unploughed sites and comparison of

Table 1: Research design used in the study

S.N	Treatment	Block	Area (ha)	Number of sample plots	Remarks
1	Control (T0)	1	0.24	4	Sample plot spaced between 20m x 20 m
		2	0.95	11	
		3	1.17	26	
2	Ploughed (T1)	1	0.74	6	Sample plot spaced between 30m x 30m
		2	4.79	44	

the regeneration potential of Sal between these sites using tabular form. Statistical test (*i.e.* T-test) was also performed to know the significant distribution of the target variables in different conditions.

Limitations

The study was based on the data of three years only. The trend showed by the variables may not follow the same pattern in future. The study site was not completely well drained and of profuse growth of weeds. Hence, findings of this study may not be generalized.

Results and discussion

Regeneration density Status of regeneration (seedlings and saplings) in terms of number per hectare determines the condition of the forest. Most of the regeneration were seedling (height up to 1m) whilst few were saplings (height >1m). Thus, the density of seedlings was higher than the density of saplings in all the measurements (Table 2).

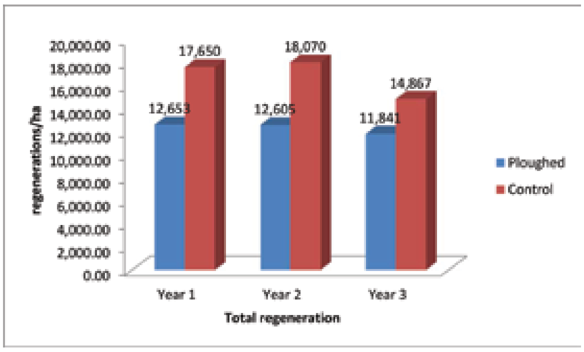


Fig. 2: Regeneration density (number per ha) in ploughed and unploughed sites

Similarly, regeneration density of Sal was found to be decreasing in both ploughed and unploughed sites in three consecutive measurements (Fig. 3). Particularly, the rate of decrease in Sal regeneration in three consecutive measurements was higher in ploughed site (66.91%, 54.54% and 51.61%) than the unploughed site (68.61%, 61.97% and 65.14%). The regeneration density of Sal was higher in unploughed site (Fig. 3).

Table 2: Density of seedlings and saplings in ploughed and unploughed (control) sites

Description	Treatment	M1 (/ha)	M2(/ha)	M3(/ha)
Seedling	Ploughed	11,682 (1407)	8,992 (1153)	7,353 (930)
	Control	15,741 (2825)	13,159 (2414)	10,656 (1969)
Sapling	Ploughed	971 (304)	3,613 (634)	4,488 (677)
	Control	1,048 (216)	4,910 (899)	4,212 (594)

Note: Standard error in parenthesis, and M1=First measurement, M2= Second measurement, M3= Third measurement

Regeneration of *Shorea robusta* shared major portion in the study area, which was followed by more than 20 different tree species such as *Syzygium cumini*, *Sapium insigne* (Dudhekhirro), *Mallotus philippinensis*, etc. In this study, regeneration density (in terms of total number of seedlings and saplings/ha) was found to be decreasing in three consecutive measurements in ploughed site while the trend was not similar in the control site. Regeneration density was higher in unploughed site than ploughed site in all the three consecutive measurements (Table 2). The difference in regeneration density was gradually being filled uptill the third measurement (Fig. 2).

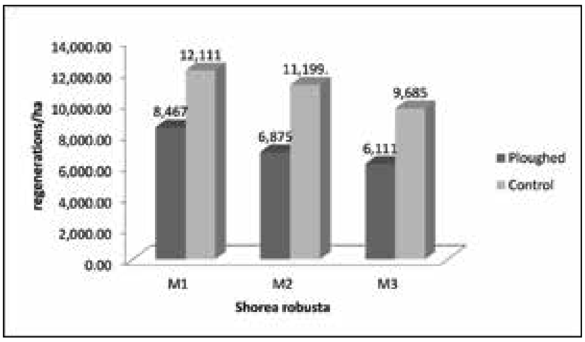


Fig. 3: Regeneration density of Sal in ploughed and unploughed sites

However, t-test for regeneration density in three consecutive measurements (i.e. p-value of 1st measurement = 0.2123, 2nd measurement = 0.1662 and 3rd measurement = 0.6471) showed that there was no significant difference between ploughed and unploughed sites. The t-test result was also the same for particularly Sal regeneration *(i.e.* p-value of 1st measurement = 0.2662, 2ndmeasurement =0.0709 and 3rd measurement = 0.0832).

Number of natural regeneration can help classify the condition of forest. In general, more the regeneration, better the forest condition. Good regeneration always remains a key for the sustainable forest management. In this study, regeneration was lower (just exceeded 18,000) than other studies conducted by Rautiainen and Suoheimo (1997), DFRS (2014a) and Ranabhat *et.al.* (2016). These studies were done in Sal forest including different stages of trees (*i.e.*, tree, pole, sapling and seedlings) and/or complete removal of weeds but this study was carried out in the degraded area with problem of regeneration. Besides this, some portion of the study area was water logged and the area was dominated by the grasses and weeds, hence the regeneration was lower than other sites.

In particular, regeneration of Sal is decreasing abruptly in the ploughed condition than control condition. In ploughed condition, soil is exposed which is good for aeration and nutrient uptake for plants compared to compact soil (Kang and Lal, 1981). This condition is suitable for plants to grow. Besides Sal, ploughed condition welcomes other tree species also to regenerate which ultimately helps in declining the density of Sal regeneration.

Species diversity

Species diversity is one of the major indicators for the status of forest ecosystem. Terai forest has diversity of tree species, where Sal is a major tree species associated with many other tree species. Species diversity was found higher in ploughed site than unploughed site (Annex 1). Altogether, 17, 19 and 23 regeneration species were found in ploughed site in three consecutive measurements whilst 14, 16 and 20 in unploughed site in the same measurements. Similar results were found in case of seedlings and saplings when analyzed separately. However, in both ploughed and unploughed sites, the number of species was found to be in an increasing trend in later measurements (Table 3).

Table 3: Total number of regeneration species in three consecutive measurements

Description	Treatment	1st measurement	2nd measurement	3rd measurement
Regeneration	Ploughed	17	19	23
	Control	14	16	20
Seedling species	Ploughed	15	17	18
	Control	10	13	17
Sapling species	Ploughed	12	17	18
	Control	13	15	15

Total regeneration was higher in the unploughed site than ploughed site until the 3rdmeasurement. But, the difference in regeneration is gradually being narrowed with the elapse of time. By ploughing the land, it could disturb the soil to grow plant for few years and also kills the plants already existed there. Thus, regeneration density becomes lower for few years in ploughed condition than control condition. Once the soil becomes suitable for plants to regenerate, the regeneration process accelerates more in the ploughed condition.

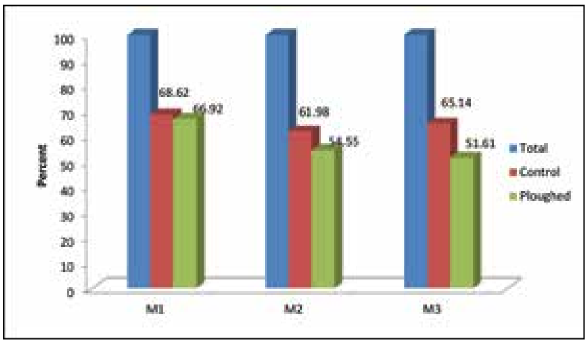
The value of Shannon Weiner diversity index was higher in ploughed site (*i.e.* 1.4, 1.56 and 1.75) than unploughed site (*i.e.*, 1.00, 1.4 and 1.4) in three consecutive measurements. It indicates that the possibility of increase in species diversity is higher in ploughed site than unploughed site.

The regeneration diversity found in this study (14 to 23 species) is more or less the same to the findings of (Ranabhat *et. al.,* 2016 ; Sapkota *et al.*, 2009), though research sites condition were different. The tree species diversity at the seedling stage was higher than that of sapling stage in both ploughed and unploughed sites. Similar findings were reported in previous studies (Ranabhat *et al*., 2016; Sapkota *et al.,* 2009). However, regeneration density was found to be higher in the ploughed site than unploughed site. Ploughed condition offers conducive environment for many species for regeneration, which may be one of the reasons of high species diversity. All the seedlings may not reach at the sapling stage due to adverse condition, which leads to reduction in species diversity at the sapling stage.

Species composition

Composition of species was dominated (in terms of frequency) by Sal in both ploughed and unploughed sites. It represented more than half of the total regeneration. Sal dominates in the forestsof Terai and Chure regions of Nepal by 32.25% (DFRS, 2014a) and 30.42% (DFRS, 2014b), respectively. The same results are reported by (Giri *et al*., 1999;Paudyal, 2013; Acharya *et al.*, 2009 and Sapkota, *et al*., 2009). However, domination of Sal was higher in unploughed site than ploughed site. After Sal, domination of other species was found different in both ploughed and unploughed sites (Annex 2).

In general, the domination of Sal was found to be decreased in both ploughed and control plots in three consecutive measurements (Fig. 4). It shows that the share of other species increased every year. However, domination of Sal was found to be decreased more in ploughed site than unploughed site (Fig. 4). Result shows that the chance of regeneration of other species in the Sal dominated area is higher when it is ploughed.



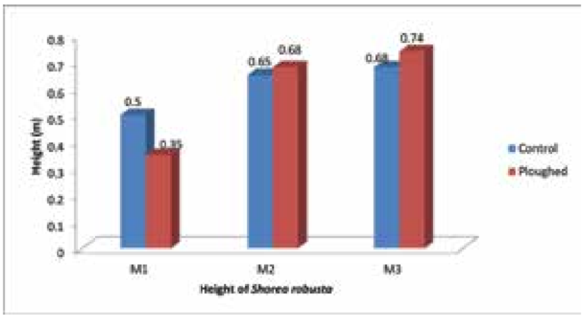
Note: M1=First measurement, M2= Second measurement, M3= Third measurement

Fig.4: Domination of Sal in three different consecutive measurements

Height growth

In the first measurement, mean height of Sal was found to be higher in the unploughed plots. Contrastingly, second and third measurements showed opposite results (Fig. 5). The presence of some Sal regeneration in control plots during establishment might have caused to increase height growth in the first measurement.

Result shows the rate of height growth is higher in ploughed site than unploughed site. However, T-test showed that mean height of *S. robusta* was not significant in both ploughed and unploughed sites except in the first measurement (p1=3.45e-15, p2=0.5494, p3=0.2404).



Note: M1=First measurement, M2= Second measurement, M3= Third measurement

Fig.5: Mean height of Sal in three consecutive measurements

In the favorable condition, height growth of Sal is fast in the initial (regeneration) stage up to 6m after five years from the seed (Jackson, 1994). Height of the regeneration of Sal increases more in the absence of shelter trees (Rautiainen and Suoheimo, 1997). Result of the study shows that ploughed condition is more favorable to height growth of Sal compared to normal condition. However, the result is opposite to the general findings i.e. as height of tree increases as it grows in dense. But, exposure of soil helps in nutrient uptake and good aeration which may be the reason to increase the height of Sal irrespective of its density.

Conclusion

It is well documented that degradation of Sal forests is the result of heavy grazing, lopping and fire. The degraded condition of the Sal forest can be enhanced to the similar condition of the good natural forest in long run if it is conserved well (Ranabhat *et al*., 2016). The satisfactory results of regeneration have been achieved even in the degraded area in this study. Thus, it is clear that protection from grazing and fire is the foremost requirement for regeneration of Sal.

Tree species diversity can be maintained in the degraded Sal forest area. However, ground work (*i.e.* exposing soil) is necessary to increase tree species diversity at the cost of losing the dominance of Sal species. Similarly, ground work also supports to increase height growth of Sal regeneration.

All the studied variables (such as regeneration density, species diversity, height growth) do not differ significantly in the ploughed and unploughed sites until the five years of establishment. The result shows that the impact of the ground work (*i.e.* complete ploughing using machine) is ineffective to bring substantial differences in the growth of Sal regeneration and species diversity but increases cost of management. Based on this study, it can be concluded that complete ground work using machine in degraded Sal forest may not be an essential task for Sal forest management from both ecological and financial point of view. However, complete protection from grazing and fire seems foremost tasks to manage degraded Sal forest in the Terai region.

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Annex 1: Tree species in ploughed and unploughed (control) sites

S.N.	Latin name	Local name	Control (T0)	Ploughed (T1)
1	*Shorea robusta*	Sal	√	√
2	*Terminalia alata*	Asna	√	√
3	*Dalbergia sissoo*	Sisso	√	√
4	*Acacia catechu*	Khair	---	√
5	*Azadirachta indica*	Neem	√	---
6	*Syzygium cumini*	Jamun	√	√
7	*Sapium insigne*	-	√	√
8	*Mallotus philippinensis*	Sindure	√	√
9	*Terminalia belerica*	Harro	---	√
10	*Aegle marmelos*	Bel	√	√
11	*Psidium guajava*	Amba	√	---
12	*Pterocarpus marsupium*	Bijaysal	---	√
13	*Diospyros melanoxylon*	-	√	√
14	*Schleichera oleosa*	Kusum	√	√
15	*Holarrhena pubescens*	-	√	√
16	*Dalbergia latifolia*	Sati sal	---	√
17	*Careya arborea*	-	---	√
18		Kachari	√	√
19		Ghurmusrani	√	√
20		Tikuli	---	√
21	*Terminalia chebula*	-	---	√
22	*Myrsine semiserrata*	-	√	√
23	*Ficus glomerata*	-	√	---
24	*Lagerstroemia parviflora*	Botdhairo	√	√
25	Unknown1	-	---	√
26	Unknown2	-	---	√
27	*Artocarpus lakoocha*	Katahar	√	---
28	*Leea crispa*	-	√	---

Annex 2: Composition of ten major species in three consecutive measurements

SN	Latin name	Composition (%)			Latin name	Composition (%)		
		Control (T0)				Ploughed plots (T1)		
		M1	M2	M3		M1	M2	M3
1	*S. robusta*	68.62	61.98	65.14	*S. robusta*	66.92	54.55	51.61
2	*S. cumini*	14.43	10.63	7.18	*M. philippninensis*	7.38	7.83	6.59
3	*M. philippninensis*	4.15	3.87	5.22	*S. insigne*	5.98	0.88	4.7
4	*S. oleosa*	4.38	3.44	3.13	*T. belerica*	3.43	3.54	3.23
5	*P. marsupium*	1.73	1.29	2.48	*P. marsupium*	3.31	4.42	4.97
6	*H. pubescens*	0.92	8.81	9.5	*S. oleosa*	3.31	2.27	3.49
7	*S. insigne*	0.23	6.66	2.35	*A. marmelos*	3.18	1.77	2.02
8	*A. marmelos*	0.57	1.18	0.65	*H. pubescens*	1.27	19.44	16.94
9	*T. alata*	0	0.64	0.91	*S. cumini*	1.4	1.14	1.08
10	*P. guajava*	0.34	0.32	0	*A. catechu*	0.76	0	0

Note: M1=First measurement, M2= Second measurement, M3= Third measurement