



Research article

Effect of tree canopy opening in the regeneration layer of Terai Sal (*Shorea robusta* Gaertn.) forest in Western Nepal: A case study

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Abstract: A study about the effect of tree canopy opening in the regeneration layer of Sal (*Shorea robusta*) forest was investigated in four strata of forest viz. 0–25, 25–50, 50–75 and 75–100 percentage crown cover vegetation in Buddha-Shanti Collaborative Forest Management of Nawalparasi district, Nepal. Systematic sampling was carried out for regeneration survey in two sub-compartment of each 10 hectare, where in one sub-compartment was (C1S2) silviculturally managed where Irregular shelter wood system was adopted with regeneration felling and the other sub-compartment (C1S3) was undisturbed with no regeneration felling. The seedling density of Sal was found higher in the 0–25 and 25–50 percentage crown cover (22,167 ha⁻¹ and 13,667 ha⁻¹) respectively than 50–75 and 75–100 percentage crown cover area (11,667 ha⁻¹ and 11,000 ha⁻¹) respectively. Likewise, sapling density was also higher in the open canopy than dense or closed canopy. Crown cover percentage was found negatively correlated with regeneration density per hectare (ha) in Sal forest. Hence, the study concluded that open canopy favours regeneration; promotes seedling density in Sal forests and regeneration layer of Sal is dependent on canopy opening or threshold light intensity for better growth and survival.

Keywords: Crown cover - Regeneration felling - Seedling.

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INTRODUCTION

Shorea robusta Gaertn. (Commonly known as Sal tree) is a tropical tree species native to Indian subcontinent, ranging south of the Himalaya, from Myanmar in the east to Nepal, India and Bangladesh (Tiwari 1995). One of the most important timber species of Nepal, it is found mostly in the Terai region from east to west, especially in the Siwalik Hills (Churia Range) in the subtropical climatic zone (Jackson 1994, DFRS 2015). In addition, the species is regarded as a climax formation throughout and also capable to colonize new areas with heavy growth of seedlings. However, it prefers the Bhabar region and the alluvium of Terai where water logging does not happen (DFRS 2015). Sal forms extensive forest and gregarious in nature. At the national level, Sal has the highest stem volume 31.76 m³ ha⁻¹ which is 19.28% of total stem volume of the country (DFRS 2016).

Canopy cover describes the proportion of the forest floor covered by the vertical projection of the tree crowns (Avery & Burkart 1994, Cook *et al.* 1995). Canopy cover affects plant growth and survival; hence determining the nature of the vegetation. It is an important ecological parameter of forest ecosystem for its relationship with natural regeneration and species richness (Ganey & Block 1994, Zollner & Crane 2003). In addition, regeneration status of a forest is very important for its health and vitality as healthy forest ensures good future regeneration. The regenerating and productive character of forest is determined by presence of different age-group of seedling, sapling and tree (Chauhan *et al.* 2008). Moreover, regeneration is measured to determine whether it meets the objective of forest management, and in particular, whether the productive capacity and biological diversity of forest are maintained (Lutze *et al.* 2004). The natural regeneration in sal forest is adversely affected by external factors such as heavy grazing, extensive lopping and forest fire. Furthermore, Sal

forests of Terai are under continuous anthropogenic pressure and consequently, at present are shrinking and exhibit very poor regeneration status (Bajpai *et al.* 2018). In addition, the regeneration of Sal in moist Bhabar natural forest is really a problem (Subedi 2011, Bajpai *et al.* 2015). However, this is not the case for community managed forests as they are well protected from fire, grazing and lopping activities and timely application of silvicultural operation (Awasthi *et al.* 2015, Cedamon *et al.* 2018).

The scientific management of forest emphasizes that forest should be managed scientifically following appropriate silvicultural system, while appropriate tree felling and regeneration activities are integral part of it (DoF 2014). Shrestha (1992) and Sapkota (2009) reported that forests subjected to moderate level of canopy opening enhanced regeneration performance and maintained species diversity in Sal forest in Nepal, which in turn could be touted as a management tool for Sal forests. Gaps on forest canopy represent opportunities for forest regeneration but has been used little by foresters in developing silviculture regimes (O’Hara 2014). In Nepal research on Sal forest management is relatively recent and studies particularly on growth and development of this species also remain scant. In this context, this study was an attempt to analyze the effect of canopy opening in regeneration layer of Terai Sal forest in Nepal and information could be a valuable for developing Sal forest management plan in future.

MATERIALS AND METHODS

Study area

The study was carried out in Buddha-Shanti Collaborative Forest (BSCoF) which is located in Sunawal municipality, Ramgram municipality and Palinandan rural-municipality of Nawalparasi district in western Nepal (Fig. 1). The study site occupies an area of 1781.32 ha of which 1204.10 ha covers core area and 577.22 ha as fringe area. It is located between 27° 30' 00" to 27° 40' 00" latitude and 83° 35' 00" to 83° 40' 00" longitude. Altitudinal variation of the study area ranges from 200 m to 300 m to above mean sea level (BSCFMG 2014).

BSCoF Management group includes 11,422 households from Sunawal municipality (ward 7, 8, and 9), Ramgram municipality (ward 6, 10, 14, 15 & 16 & Palinandan rural municipality (ward 4, 5, & 6). The forest area is dominated by *Shorea robusta* (Sal) with other associates such as *Terminalia alata* Heyne ex Roth (Saj), *Haldina cordifolia* (Roxb.) Ridsdale (Karma), *Semecarpus anacardium* L. (Valayo), etc. (BSCFMG 2014).

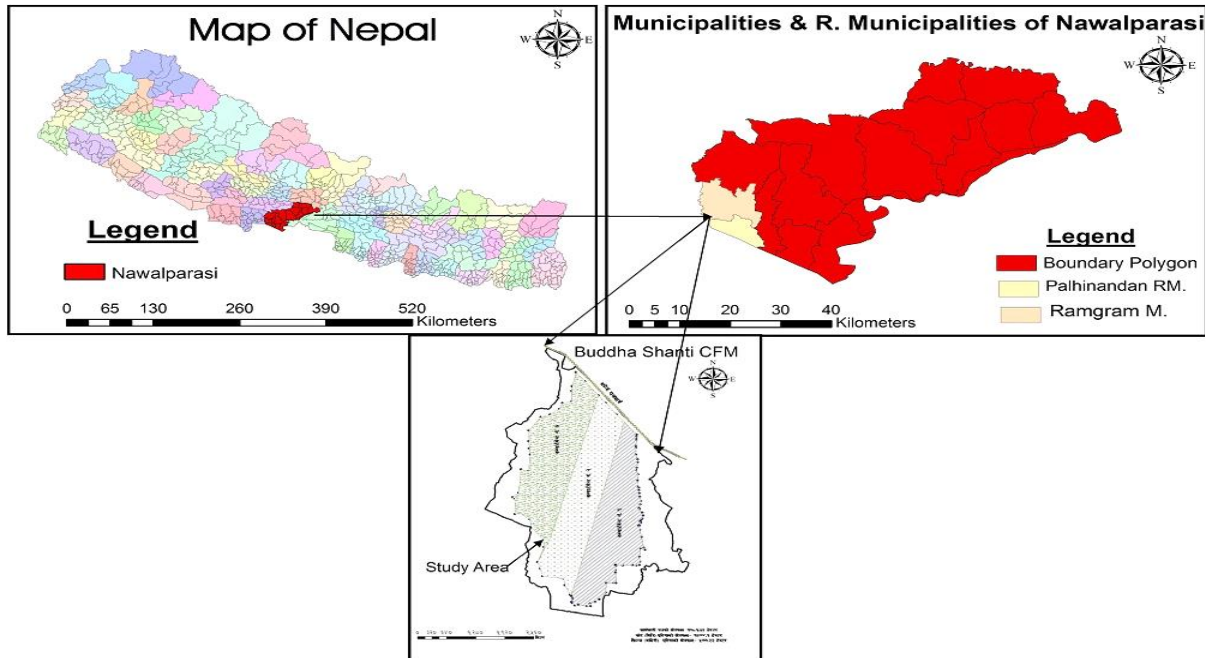


Figure 1. Map representing the study area.

In BSCoF, Irregular shelter wood (irregular) system has been applied for its management under 10 year regeneration period and rotation period is 80 years (Troup 2008, BSCFMG 2014). Recommendation of this system is based on species *i.e.* Terai Sal (*Shorea robusta*) forest (BSCFMG 2014, Subedi *et al.* 2018). The whole forest area was divided into three compartments and each compartment has eight sub-compartments (periodic blocks) under 10-year regeneration period. Number of compartment were based on forest area (maximum area = 400 ha). Regeneration felling is concentrated in one sub-compartment of each compartment where majority of over mature trees exist and regeneration is in comparatively poor condition (BSCFMG 2014).

Forest sampling

For regeneration survey parts of two sub-compartments (*i.e.* C1S2 and C1S3) of compartment one (C1) each of 10 hectare were taken. Sub-compartment C1S2 was taken as open canopy strata where Irregular shelterwood system was adopted with regeneration felling and sub-compartment C1S3 was taken as medium or dense canopy strata which was undisturbed. Individual plants were categorized into seedling (ht < 1.3 m) and saplings (dbh < 10 cm and ht > 1.3 m) as recommended by Forest inventory guideline of Government of Nepal (DoF 2004). A total 20 sample plots were laid out in the study area following systematic sampling with 0.25% intensity help of ArcGIS 10.3. The quadrants of 5 m × 5 m for sapling and 1 m × 1 m for regeneration were laid out (DoF 2004). Densiometer was used to find the crown cover percentage.

Data analysis

The regeneration parameters were analyzed using MS-Excel and SPSS. Correlation and Regression analysis was used to assess the effect of canopy opening on regeneration layer of Sal forest. For calculating density of Sal and other plant species, the total number of each species in all the plots were determined, and was converted into plants per ha.

RESULTS

Regeneration status

The study found higher seedling and sapling densities in the sub-compartment (C1S2 *i.e.* managed area) with regeneration felling as compared to that in the sub-compartment (C1S3 *i.e.* unmanaged area) with no regeneration felling. Accordingly, Compartment was found to have 35,834 seedlings ha⁻¹ with 22,667 seedlings ha⁻¹ in Compartment (Fig. 2). Similarly, sapling density was also reported higher in managed Compartment (open strata) 6,200 ha⁻¹ as compared to unmanaged Compartment (closed strata) 3400 ha⁻¹. Furthermore, both seedling (29,834 ha⁻¹) and sapling density (5,934 ha⁻¹) of Sal was found to be higher in managed compartment than in unmanaged compartment (seedlings 15,833 ha⁻¹ and saplings 2,867 ha⁻¹).

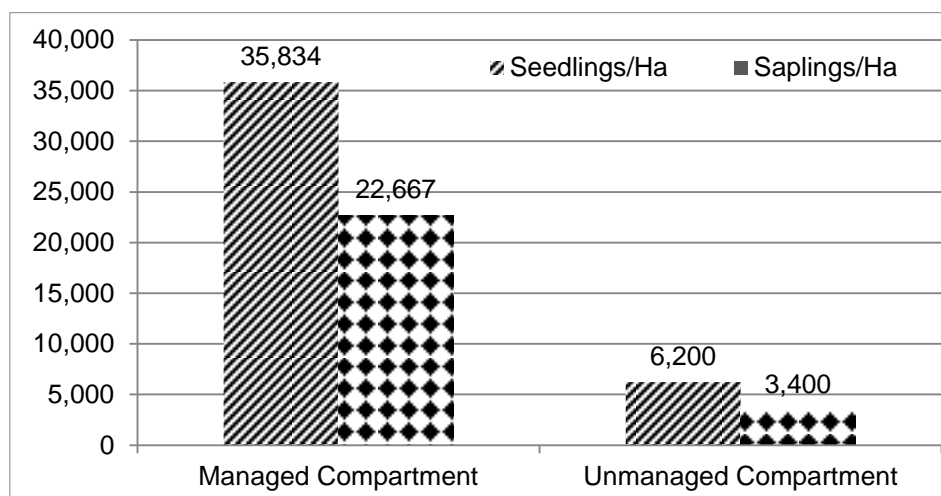


Figure 2. Seedlings and saplings density in the study area.

Crown cover and regeneration density

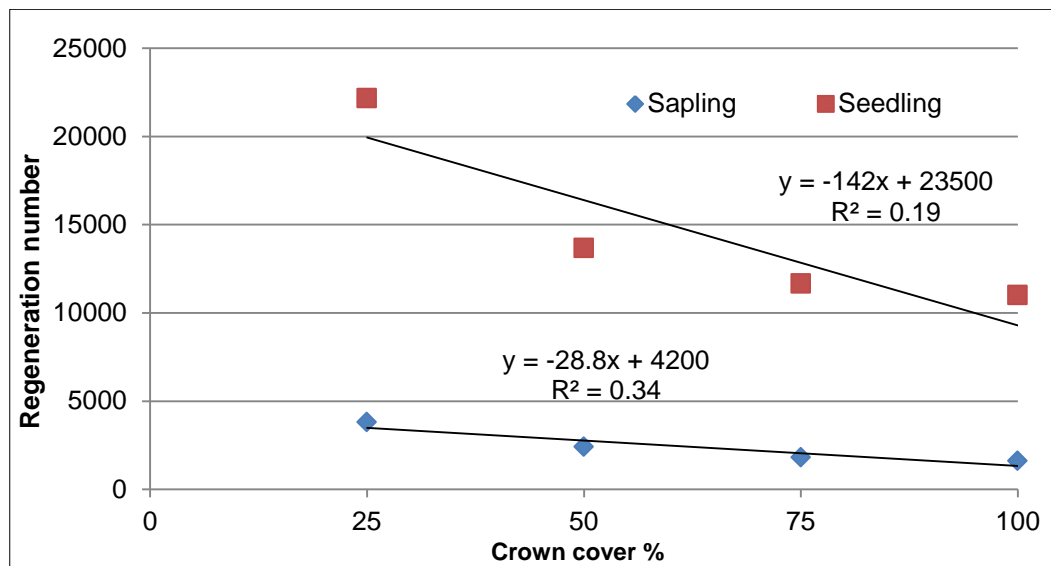
The study found that the regeneration density was higher with decreased crown coverage in managed Compartment and lower with increased crown coverage in unmanaged Compartment which is shown in table 1. Both seedlings and saplings density was maximum in 0–25 crown cover % (*i.e.* open strata) with 22,167 and 3,800 number per ha respectively and minimum in 75–100 crown % (*i.e.* closed strata) with 11,000 and 1,600 number per ha respectively. The results also shows that with the increasing crown cover percentage the regeneration of Sal is decreasing which indicates that opening of crown and intensity of light is necessary for the regeneration to Sal.

Relation between Crown cover and regeneration density

The relationship between forest canopy cover and regeneration largely depends on two key variables: species ecology and dynamics of forest canopy in time and space (Zollner & Crane 2003). The study concluded that there is no linear relationship between increasing canopy cover and regeneration layer of Sal forest (with adjusted R² value 0.19 and 0.34 for seedlings and saplings respectively) (Fig. 3). This suggests that the growth and regeneration capacity in Sal forest is governed by the opening of the canopy to some extent.

Table 1. Crown cover and regeneration stock per ha in the study area.

Crown cover %	Species	Regeneration Count		Per Hectare Regeneration density	
		Seedling	Sapling	Seedling	Sapling
(0–25)%	<i>Shorea robusta</i> Gaertn.	112	55	18667	3667
	<i>Terminalia alata</i> Heyne ex Roth	17	2	2833	133
	<i>Semecarpus anacardium</i> L.	4		667	0
	Total	133	57	22167	3800
(25–50)%	<i>Shorea robusta</i> Gaertn.	67	34	11167	2267
	<i>Terminalia alata</i> Heyne ex Roth	15	2	2500	133
	Total	82	36	13667	2400
(50–75)%	<i>Shorea robusta</i> Gaertn.	50	25	8333	1667
	<i>Terminalia alata</i> Heyne ex Roth	20	2	3333	133
	Total	70	27	11667	1800
(75–100)%	<i>Shorea robusta</i> Gaertn.	15	6	7500	1200
	<i>Terminalia alata</i> Heyne ex Roth	3	2	1500	400
	<i>Haldina cordifolia</i> (Roxb.) Ridsdale	4		2000	0
	Total	22	8	11000	1600

**Figure 3.** Relation of crown cover with regeneration stocks of the forest.

DISCUSSION

The regeneration stature of a forest indicates its health and vitality as a healthy forest promotes good future regeneration. There is a significant variation in regeneration number between managed compartment with regeneration felling and unmanaged compartment with no regeneration felling (Fig. 2). The study shows a higher number of both seedling and sapling densities in the managed areas than in unmanaged area which could be attributed to the regeneration felling (*i.e.* canopy opening). This is in line with the report of Sapkota *et al.* (2009) who asserted that regeneration of most of the tree species including Sal is favored by moderate level of disturbance than undisturbed area. Both seedling and sapling density of Sal was found to be higher in the managed compartment and low in the unmanaged compartment. This aligns with previous researches (Khan *et al.* 1986, Awasthi *et al.* 2015, Subedi *et al.* 2018) who reported that survival and better growth of Sal seedlings in the forest periphery compared to those under dense canopy. Furthermore, Suoheimo (1999) also opined a higher number of seedling and sapling densities after the regeneration felling of Sal forests under the uniform Shelterwood system in Nepal.

Canopy cover is one of the important factor in the study of plant growth and development as it influences numerous ecological processes in forest communities (Cook *et al.* 1995, Zollner & Crane 2003, Berger & Rey 2004). The study found that both seedling and sapling density was higher in open canopy than in dense or close canopy. There was a distinct variation in the regeneration density with respect to crown coverage, as increase in crown coverage there decrease in the regeneration density. Compared to other species, both seedling and sapling density of Sal was found to be higher in the open canopy than in the dense or close canopy which shows the

impact of canopy opening in regeneration performance in Sal forest. Therefore, the results clearly depicts that as per increasing crown cover the regeneration density of Sal is decreasing which suggests that opening of crown and intensity of light is an important factors for regeneration of Sal forest. Troup (1986) and Awasthi *et al.* (2015) reported that regeneration performance of *S. robusta* was observed better in open space rather than under shade. Likewise, Shrestha (1992) and Gautam & Devoe (2006) also opined that Sal regeneration is prolific wherever openings are made and protected. Furthermore, our finding justified with that of Khan *et al.* (1986) and Sapkota & Oden (2009), who reported that better growth and survival of *Shorea robusta* regeneration on open canopy compared to those under dense or closed canopy, which illustrates the better growth and regeneration in presence of canopy opening or threshold light intensity for the process of photosynthesis in regeneration layer. This study shows no linear relation between regeneration density and higher canopy coverage. In addition Pearson correlation coefficient evidences that both seedlings ($r = -0.889$; $p\text{-value} = 0.008$) and sapling ($r = -0.936$; $p\text{-value} = 0.46$) of Sal regeneration have a negative linear relationship with crown closure. This suggests that the number of regeneration capacity of Sal governed by the extent of canopy opening and threshold light intensity. Thus, regeneration felling and canopy opening is an important intervention for Sal forest management.

CONCLUSION

The results highlighted that the density of seedlings and saplings, the growth performance of regeneration of *Shorea robusta* has been found to be remarkable in the managed compartment than in unmanaged natural stands. The study also found that there is no linear relationship between higher canopy coverage and regeneration density of Sal forest *i.e.* increase in canopy coverage decrease the regeneration density. The study concluded that canopy opening and light intensity has direct positive effect on regeneration layer of Sal forest. Hence, the study recommends that measure of forest canopy should be an important factor for long term management of *Shorea robusta* forest.

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