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Canopy Gaps and Regeneration Development in Pine and Sal Forests Silviculture Demonstration Plots in Midhills Nepal

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Abstract

Silviculture demonstration plots were established in Kavre and Lamjung districts by the EnLiFT Project to examine stand response to selected silviculture system – uniform shelterwood, selection system, and negative thinning and as a showcase to forest users for these silviculture system. This paper analysis the extent of canopy gaps on these demo plots after silviculture treatments and regeneration development one-year after treatment. Using crown photographs, crown covers are estimated and compared between silviculture systems. The analysis have shown that rigid silviculture systems like shelterwood and selection system can create significant canopy gaps than negative thinning in pine plantations and that the rate of natural regeneration is directly related with the canopy gaps. In Sal-Katus-Chilaune forest however, negative thinning created canopy gaps larger than selection silviculture demo plots due to removal of 4-D trees, majority are Chilaune trees, which typically have large spreading crown. Although conclusion from the demo plots at this stage may be too early to make on regeneration growth and canopy gap relationship, it is clear that silviculture operations have significant role in promoting higher rate regeneration growth and that rigid silviculture operations like selection and shelterwood systems are better than current silviculture regime represented by negative thinning in this study.

Keywords: Community forestry, canopy gaps, multiple-use forestry, selection system, shelterwood system

1. Introduction

The Government of Nepal (GoN) is strongly campaigning for commercialisation of forest management through scientific forest management (SFM) to meet the country's demand for timber and fuelwood (MFSC, 2016). The Department of Forests (DoFs) promote active silvicultural programs such as shelterwood and selection silviculture or modification of these silviculture systems as approaches for SFM. While it generally understood that any silviculture system involves harvesting of overstory trees either singly or in groups to promote tree regeneration (O'Hara, 2002), there is a lack of understanding on regeneration development following harvesting or silviculture treatments on community forests in Nepal Mid-hills. To address the lack of silviculture understanding, the EnLiFT Project[2] embarked on a silviculture

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action research to demonstrate shelterwood and selection silviculture systems and to examine forest ecological responses and forest users responses on these systems. The aim of this paper is to report the extent of canopy gaps and regeneration development in these demonstration plots after one year since implementation of silviculture regimes.

Gaps on forest canopy represent opportunities for forest regeneration and had been studied widely (O'Hara, 2014) but has been used little by foresters in developing silviculture regimes. The interest in understanding forest gaps in silviculture is due to opportunities it presents for wider range of forest management objectives including resilience and adaptability (Kern *et al.,* 2016). Typical silvicultural regimes developed based solely timber-centred attributes presents some challenges when applied in community forests due to diverse forest management objectives including commercial and subsistence demand for timber and non-timber forest products and environmental conservation (Cedamon *et al.,* 2016). For example, when the aim of forest management is increasing fodder and forest litters, silviculture program may need to consider sizes and frequency of forest openings so that fodder and litter production is supported. The EnLiFT Silviculture Demo Plots therefore present opportunities for examining regeneration development, growth and survival of planted fodder crops given canopy gaps resulting from different silviculture regime.

2. Overview of Silviculture Practice in Nepal's Community Forests

Community forestry was initiated in several developing countries primarily to reverse land degradation Community development and livelihood outcomes were initially perceived as secondary outcome but has become a dominant objective gaining national governments and international community. While the contribution of community forestry in improving forest cover, social cohesion and rural income, globally community forestry has underperformed or community forestry goals rarely achieve. Several authors have argued that a key success factor for community forestry is its ability to provide early and regular supply of materials to forest user (Calderon and Nawir, 2006 in the Philippines; Pokharel, 2011 in Nepal).

3. Background to EnLiFT Silviculture Action Research

The EnLiFT Project silviculture action research has established silviculture demonstration plots in Chaubas and Dhunkarka village development committees (VDC) in Kavre district and in Tandrang Taksar VDC in Lamjung district. The purpose of the silviculture action research is two-fold. First the demonstration plots established as a learning site by community forest users groups (CFUGs) on how to implement a number of silviculture systems potential for their forests. Secondly, the demonstration plots serves as experiments where tree and stand response can be measured to guide development of silviculture regimes for active and equitable community forest management. This paper reports the crown cover and natural regeneration growth in the demonstration plots from Chaubas and Tandrang Taksar representing Pine plantation and naturally regenerated Sal forests, respectively. Crown cover and regeneration growth in Dhunkarka VDC is not reported due to delayed treatment of one plot.

4. Silviculture Trial Design and Analytical Framework

The silviculture demonstration plots in Chaubas VDC is located in the Chapani community forest. The plantation has an area of 85 hectares (ha) dominated by Gobre (*Pinus wallichiana*) and Pathe Salla (*Pinus patula*) approximately 35 years old. The silviculture demonstration plots in Tandrang Taksar VDC is located in Lampata community forest, which is a Sal-Chilaune with a total forest area of 50 ha. These forests are mainly managed for timber but like any community forest is generally undermanaged due to strong conservation ethos and lack of silviculture skills of forest users. To address this skills gap, hands-on training on silviculture management were provided to participating community forest user groups. The demonstration plots served a training ground as well as participatory research site where observations on the tree and forest response to silviculture is collaboratively undertaken by EnLiFT researchers and forest users.

In Chapani community forest, four demonstration plots were established each having a dimension of 60m x 70m. In Lampata community forest, three demonstration plots were established each having a dimenstion of 50m x 80m. The treatments are described in Table 1. Some trees were felled in each plot following single tree selection system based on Q factor[3], shelterwood system following Nepal SFM Guideline 2015 and cutting dead, dying, deformed, disease (4-D) trees. The pretreatment tree density, post treatment tree density and the volume of timber harvested from the demonstration plots are provided in Table 1. After silviculture treatment, the forest floor is cleared from harvesting debris and weeds to prepare the ground for regeneration. All silviculture operation were conducted in Feb-April or during the driest months of the year. In Chapani community forest the silviculture operations were conducted in April to May 2015 and the seedling count was conducted in January 2017, while in Lampata silviculture operations were conducted in January to March 2016 and seedling count was made in January 2017.

Table 1. Depicts the silviculture treatments at Chapani community forest.

Silviculture treatments in Chapani community forest- Chaubas, Kavre	Pre-treatment tree density (stems per ha)	Post-treatment tree density (stems per ha)	Volume harvested due to silviculture treatment (m^3/ha)
Negative thinning - **harvesting 4D trees only**	416	283	60
Single tree selection for mixed pine and broadleaves timber production – **using Q factor**	504	185	300
Single tree selection for timber-fodder forest garden – **using Q factor**	535	147	200
Uniform shelterwood system – **using the SFM guideline 2015**	361	50	243
Silviculture treatments in Lampata – Tandrang Taksar, Lamjung			
Negative thinning – **harvesting 4D trees only**	1412	1167	38
Single tree selection for timber production - **using Q factor**	953	780	173
Single tree selection for timber-fodder forest garden - **using Q factor**	1253	963	52

Tree measurements were by conducted jointly by EnLiFT and forest user groups (FUGs) following the Rapid Silviculture Appraisal Technique described by Cedamon *et al.* (2016)

3 The selection system based on Q factor is described by the same authors on another paper in this proceedings.

before the silviculture operations to estimate timber stock and derive stand table. The timber stock table was used by the FUG to apply for harvesting permit while the stand table was used in participatory and bilateral dialogues aimed at collaboratively determining silviculture systems appropriate for silviculture demonstration for the given forest characteristics. Tree measurement data include diameter at breast height (DBH), species local name, total tree height, and crown radii. Eight photographs of the canopy were taken from corners of 10m x 10m subplots within the plot at 57.5 degrees from the zenith ordinary (without hemispherical lens) using digital cameras to obtain estimate of canopy cover. Canopy cover is defined in this study as the proportion of the forest floor covered by the vertical projection of the tree crowns (Jennings *et al.,* 1999). Canopy photographs were processed using CanEYE software (freely downloadable from https://www6.paca.inra.fr/can-eye/Download) to obtain estimate of canopy cover. Canopy gaps are then estimated as ***100- crown cover (%)*** because this value is more appreciated by forest users particularly in terms of regeneration development.

5. Results

5.1 Canopy Gaps Created by Silvicultural Regimes

It is generally understood that forest canopy determines the microhabitat within the forest controlling the recruitment and growth of new plants and animal activities. All silviculture activities alter forest canopy and stand structure to some degree necessary for improving health and growth of existing forest and development of future forests. The EnLiFT silviculture demonstrations had showed that different silviculture systems create a different canopy profiles as measured by canopy gaps and that these differences is more evident in Pine plantation that in naturally regenerated Sal.

In Chapani forest, which is an even age pine plantation, the average canopy gap before silviculture treatment is between 34-44%. Negative thinning increase the canopy gap by about 11%, selection silviculture fore fodder-timber forest garden increased the gap by 28%, selection silviculture for timber production has increased the canopy gap by 24% while shelterwood system increased the gaps by 43% (Table 2). The differences on canopy gap on timing of measurements (before and after silviculture treatment) and between silviculture treatments is found to be statistically significant based in analysis of various (ANOVA) where p value is =0.000. There was also a significant interaction (p value = 0.000) between timing of measurement and silviculture treatments indicating that differences of canopy gaps that some silviculture treatments results in considerably larger canopy gaps than others. From Table 2, it is clear that negative thinning retain more than half of canopy cover, selection silviculture retains 28-40% of crown cover while shelterwood retain 14% of crown cover.

A relatively different canopy gap profile has been found in naturally regenerated Sal forest in Lampata community forest. As shown in Table 2, the average canopy gaps before silviculture treatment ranges form 7-9% while after silviculture treatment ranges 48-53% across treatments. Canopy gaps has been increased by 45% in negative thinning while selection silviculture increased canopy gaps by 38% for selection for fodder-timber forest garden and 41% for selection silviculture for timber production. While it is clear that canopy gaps before and after treatment are significant, the differences canopy gaps between treatments are not significant (p value = 0.072), indicating that generally negative thinning and selection silviculture have the same effects on canopy gaps creation on naturally regenerated Sal stands.

Table 2. Canopy gaps (%) before and after silviculture treatments in Chapani and Lampata community forests in mid-hills district.

Silviculture Treatment	Canopy Gap (%)			
	Before Silviculture Treatment		After Silviculture Treatment	
	Mean	S.E. of Mean	Mean	S.E. of Mean
Chapani community forest				
Negative thinning	34.31	1.36	45.28	2.19
Selection for Fodder-Timber Forest Garden	44.31	.99	72.27	2.96
Selection for Timber	35.65	1.20	59.39	2.51
Shelterwood	44.07	1.13	85.59	1.96

Lampata community forest

Silviculture Treatment	Crown cover (%)			
	Before Silviculture Treatment		After Silviculture Treatment	
	Mean	S.E. of Mean	Mean	S.E. of Mean
Negative thinning	7.75	.52	52.83	1.82
Selection for Fodder-Timber Forest Garden	9.26	.97	46.99	1.41
Selection for Timber	6.78	.38	47.96	1.90

5.2 Relationship of Canopy Gap and Natural Regeneration Growth

Following silviculture operations, seedling survey were undertaken in in the demonstration plots. It was found that in Chapani pine plantation only 23% of the seedling subplots have regeneration while for selection silviculture for fodder-timber fodder forest garden is 100%. The seedling density varies on average of 26,000 to 223,000 seedlings per ha in pine plantation. In Sal-Chilaune forest, there is high occurrence of regeneration ranging from 79% to 100% and the seedling density is 52,000 to 55,000 seedlings per ha (Table 3). It is notable however that for pine plantation, seedling occurrence is higher in selection silviculture plot where fodder was planted and lower in negative thinning demo plot. Although all plots were had been subjected to the same level weed slashing and debris removal after harvesting, the fodder-timber selection plot has almost twice the number of regeneration than the shelterwood plot although it has slightly lower average canopy gap. In Lampata demo plots, negative thinning has the lowest seedling density among the three plots while fodder-timber selection plot has the highest seedling occurrence.

Table 3. Regeneration occurrence, seedling density and canopy gaps for silviculture treatments in Chapani and Lampata community forests.

Silviculture Treatment	Proportion of regeneration sub-plots with seedlings (%)	Seedling density (seedlings per ha)	Average canopy gap after silviculture operation (%)
Chapani demo plots			
Negative thinning	0.23	26,000	45.3
Selection for Fodder-Timber Forest Garden	1.00	423,667	72.3
Selection for Timber	0.53	54,000	59.4
Shelterwood	0.97	223,667	85.6

Lampata demo plots

Negative thinning	1.00	52,857	52.83
Selection for Fodder-Timber Forest Garden	0.86	91,786	46.99
Selection for Timber	0.79	55,357	47.96

6. Discussion and Concluding Remarks

The silviculture demonstration plots establishment through the support and facilitation of EnLiFT in Kavre and Lamjung had played a key role in changing people perspective in managing community forests for better livelihoods. Not only that the plots had served as practical learning grounds for basic forestry management and operations but it also has produced hard data on the impact of silviculture interventions on forest and stand. It has been found that significant proportion of the canopy has been opened because of silviculture intervention, which these canopy gaps can be utilised to promote growth of timber and non-timber plants. Based on canopy gaps created, shelterwood and selection silviculture can be considered rigid stand intervention on pine plantation while negative thinning is less rigid. For Sal-Chilaune forest however, it was found that regeneration growth differ between silviculture treatment although canopy gaps is almost similar. Although this result was not intended, negative thinning clearly created large gaps in a naturally regenerated forest compared to a pine plantation. The reason for this is generally due to the higher number of stems of 4-D trees generally Chilaune trees on Sal forests which are not present in pine plantations. This is common in many Mid-hills Sal forests where older Chilaune and Sal trees are kept as mother trees despite the low phenotypic characteristics for mother trees. With government approval to conduct negative thinning, the FUG has been given clearance to remove the bad old trees in their forest. Although it may be early to make conclusion from this regeneration growth and canopy gap study as the stand is still undergoing some development due to silviculture operation, it is clear that silviculture operations has have significant role in promoting higher rate regeneration growth and that rigid silviculture operations like selection and shelterwood systems are better than negative thinning.

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