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Crown Openness and Regeneration Status in Pine Forest

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Abstract

Silviculture is the art and science to control the establishment, growth, composition, health, and quality of forests [1]. Every silviculture system involves harvesting of overstory trees either singly or in groups [2]. This creates the gap in forest canopy which represents opportunities for forest regeneration [3]. In this research, I studied the relation between two variables: crown openness (independent variable) and regeneration (dependent variable). For this research, Chappani Gadhidanda community forest, Bhulmu-4 was selected as a research site because 5 research plots (4 treatment plots: 2 selections, 1 negative thinning, and 1 shelterwood; and 1 control plot) were already designed and constructed 3 years ago so the ample of time was there for the new regeneration to come post-harvest. Two Pine species were dominant in an upper canopy: *Pinus patula* & *Pinus wallichiana.*

Total 30 sampling points were constructed of $1m^2$ each in all the above-mentioned research plot for data collection of regeneration and crown openness. Sampling plots were constructed on the basis of a systematic sampling method within each 10m×10m crossing grid of the research plot (60m × 70m) and was laid in the SE direction. Gap of maximum tree height was maintained between the 5 research plots and sampling plots of the edge were not included of the North and West direction to maintain the buffer between 5 research plots. The result showed that there is an obvious relation between crown openness and regeneration owing to the fact that there was a significantly higher number of regenerations in the plots with more crown openness, whereas fewer number of regenerations were recorded in the plot with more crown closeness (less crown openness) and the correlation between two variables was found to be 0.9144. In One-way ANOVA test, at a 5% level of significance, crown openness and regeneration number among the research plots were significantly different. In contrast, plots 2&5 and 1&2 were not significantly different, in this regard. This research illustrates the effect of crown openness on the regeneration status of pine forest that will be useful finding in the worldwide context for the researchers and the decision-makers.

Keywords: Silviculture; Regeneration status; Crown openness; Forest canopy

Introduction

Silviculture is the art and science for controlling the organization, expansion, composition, vigor, and value of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis [1]. The establishment of forest and maintaining vigorous canopy cover depends on an assortment of successful silviculture practice and their applications based on clear management objectives. Individual or set of practices are applied according to forest circumstance and preferred outcome. Forest management is a fundamental element of forestry science that ensures proper management of both natural and plantation forests. It creates stability between biodiversity conservation and sustainable livelihood. These environmental and economic goals can only be achieved by the application of silvicultural treatments like thinning operations. Thinning is one of the major silvicultural treatments that have been applied time and again to manage the dense and overstocked stands. Thinning is the reduction of trees in an immature stand for the purpose of improving growth and form residual trees without permanently breaking the canopy [4]. Forest can live for a long time but they aren't eternal which creates the need for knowledge about regeneration potential for applied silvicultural practices for the duration of felling, because harvesting technique now must not take away harvesting necessity of future. The light condition within stands are influenced by silvicultural systems by creating vertical and horizontal stand structure, and thus also the dynamics of tree species in regeneration [5]. Regeneration is widely recognized as being a key process in determining the structure and dynamism of tropical secondary forests [6]. Regeneration is the process of renewal, restoration, and growth to make genomes, cells, organ, organ system, organisms, and ecosystems resilient to natural fluctuations or events that cause disturbance or damage (Carlson, 2007). Gaps on forest canopy represent opportunities for forest regeneration and had been studied widely [3]. The natural regeneration of vegetation is a dynamic process by which life will be restored when the vegetation has been partially or totally destroyed, through the mechanism of

the succession of species. Regeneration of plants is one of the important ways to regrowth the secondary forest cover. Survey on the natural regeneration is often carried out to support the development of forest management plans and can also provide valuable insights into the individual tree species [7]. Thinning can vary the species composition of a stand, improving the health of the remaining trees or disturbing an established ground flora to enhance opportunities for natural regeneration [8]. Thinning of the trees has observed to have a great effect on the regeneration and growing stock of trees. Light is required for the growth of most plants and is characterized by four attributes; quality, intensity, duration, and direction (Weaver and Clements, 1929). (Dangal et al., 2006) reports that a total of 23,404 hectares of plantations have been established in Sindhupalchowk and Kavrepalanchowk districts since the late 1970s and they were mostly dominated by Pine species [9] among which 40% is shared by Kavrepalanchowk district. The Department of Forests needs to promote the active silvicultural programs such as shelterwood and selection silviculture systems and modification of these silviculture systems as approaches for scientific forest management.

It is important to know about the preferred sources of information to plan and implement the conservation strategy for effective conservation and management of any natural resources. Nepal covers a forest area of 44.74% which has with time increased form the forest cover of former years but, still, the major problem lies in the applied forest management techniques. Forest management has been dominated by the conservative narratives and lacks active management of the forest. Forest management is more focused on protection but not on proper utilization [10]. The regeneration status of any forest type is essential to be assessed. Without a healthy regeneration status, forest establishment is not possible. Thought regeneration of any species depends on various site factors and silvicultural characteristics of plant species, my study contributes to the effect of silvicultural practice on regeneration status regarding other factors not significantly differ between trial plots. Four different silvicultural systems were performed in plots which are Selection silviculture system with the aim of creating Uneven-age Mixed Pine and broadleaves forest, Negative Thinning, Selection silviculture system with the aim of converting Even Age Pine Stand to Uneven Pine Fodder Forest Garden and Regular Shelterwood System. Artificial regeneration can be a solution to poor regeneration status but it is not cost-effective in every condition and carries the extra burden of work. Natural regeneration is always the best option regarding various factors if possible. A comparison between regeneration statuses of different silviculture practices provides reliable data for future planning. This result can be useful for other sites with similar forest types. This study will give a reliable way to compare the regeneration status of pine forest with other forest types. Studies have shown most of the management plans of CFs have insufficient information for users to provide complete guidance on scientific forest management [11]. The study of regeneration status in Chappani Gadhidanda CF research plots with different canopy cover established by the EnLiFT Nepal project can be helpful for future planning and implementation during the planning and working phase. It is necessary to shift from traditional to scientific management of CF. Research like this can be extremely helpful for the betterment of the CF of Nepal.

Research questions

i. Does the regeneration status differ with different silvicultural practices?

ii. Is there any relationship between crown openness and regeneration in pine forest?

Objectives of the study

The objective of this study was to find the relationship between the regeneration status of pine species and crown openness in distinct silviculture practices mentioned below;

a) Negative thinning.

b) Single tree selection system.

c) Uniform shelter-wood system.

The specific objectives of this study were;

i. To study the regeneration status and degree of crown openness on different silvicultural practices.

ii. To compare the regeneration status and degree of crown openness between the control plot and different silvicultural practices.

Limitations of the study

The main constraint in the research was the problem to recognize pine species when they were of few cm heights, which made it impossible to make the result of species wise regeneration status. On top of that; sloppy terrain, slippery pine leaves, and dense *Ageratina adenophora* and *Rubus ellipticus* in some place made it difficult to locate exact sampling point using 30m long linear tape. In addition, this research is from a small unit, thus findings may have limitations to generalize.

Research hypothesis

i. Null hypothesis (H_0) = There is no significant relation between crown openness and regeneration status.

ii. Alternative hypothesis (H_1) = There is significant relation between crown openness and regeneration status at 5% level of significance.

iii. Null hypothesis (H_{01}) = There is no significant difference between crown openness and regeneration status between Research plots.

iv. Alternative hypothesis (H_{11}) = There is significant difference between crown openness and regeneration status between research plots at 5% level of significance.

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Materials And Methods

Study area

The study area lies in Cappani CF Bhumlu-4 Chaubas, Kavrepalanchowk district of Central Nepal province no3. Situated on the SW- and SE-facing slopes of 20^0-30^0 at- the altitude of 1,800-2,000m from the mean sea level within a span of 3km in the sub-tropical region and coordinate 27.63^0N 85.78^oE. The soil is dominated by clay, red in color, mostly shallow in depth and mixed with small rocks [12]. Research plots were established in Chapani Gadhnidanda CF and FagarKhola CF by EnLiFT project. Chapani Gadhidanda CF is consisting of 84.5ha of mainly Gobresalla *(Pinuswallichiana)* although few Patesalla (*P. Patula*) are also found. Four plots measuring 60m x 70m had been established in Chapani CF in Bhulmu 4 where pegs had been installed on the corners of each 10m x 10m sub plots and rock pillars where also installed on the four major corners of the demo plot. The selection of plot location was done by some members of the CFUG who were also involved in establishing the plots (Figure 1).

Figure 1: Map of Study area.

Rationale for site selection

The main reasons for selecting the site were:

a) Research plots established by EnLiFT Project in collaboration with GoN so availability of the secondary data.

b) Research plots were established 3 years ago which is sufficient time for the regenerations to appear and grow.

c) Site was easily accessible.

d) There was only pine species which made use of densitometer more effective.

Sampling process

(Figure 2) Research site consist of 5 research plots: 4 treatment plots (two selection system with different degree of crown

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openness, 1 regular shelterwood and 1 negative thinning) and 1 control plot. Sampling plots were constructed on the basis of a systematic sampling method within each 10m×10m crossing grid of the research plot of 60m × 70m and was laid in the SE direction. Gap of maximum tree height was maintained between the 5 research plots and sampling plots of the edge were not included of the North and West direction to maintain the buffer between 5 research plots as shown in layout above. Thirty sampling points was taken from each research plots.

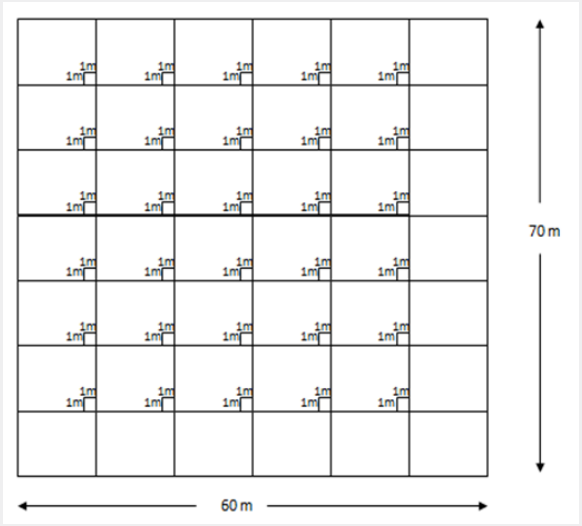

Figure 2: Sampling point design in research plot.

Data collection methods

All the data was collected during March, 2019. Data for regeneration and crown openness was collected at the same time on each sampling point. Field book data entry and sampling point establishment activities was performed with the help of CFUG.

a) Regeneration status: seedlings and saplings were considered as regeneration material [13]. Regeneration status was assessed by seedling count of different species within sample points. Seedling with its height class i.e., less than 15cm, 15-30, 30-45, 45-60, 60-75, 75-90 and above 90cm was measured with the help of 5m linear steel tape and there was no sapling present on the sampling points. Regeneration data was collected species wise but during analysis total number of regenerations was taken under consideration. Total of 1184 seeding height was measured during my research work.

b) Crown openness: Crown openness was measured with the help of Spherical Densiometer according to "The guidelines for measuring carbon stocks in community-managed forests" (Subedi et al., 2010). Crown openness data was taken from midpoint of all sampling points in all direction clockwise. 4 measurements were done in one sample point by this way total of 120 measurements for each research plot and 600 measurements in total was taken.

Data analysis

Crown openness and regeneration status of each sample plot was calculated using following mathematical functions.

Crown Openness

a) Crown closeness sum in each direction (S_{cc}) = Sum of crown closeness in 0%, 25%, 50%, 75% and 100% in that direction.

b) Crown closeness of each direction (C_c) = (S_{cc} /2400) ×100.

c) Crown openness of each direction (C_O) = 100-C_c.

d) Average crown openness of each sampling point (O) = sum of crown openness in each direction/4. i.e., $\sum_{1}^{4}(CO)/4$.

e) Mean crown openness of Research plot = Sum of average crown openness of 30 sampling points/30

i.e., $\sum_{1}^{30}(O)/30$.

For the statistical analysis, both descriptive as well as inferential statistics were used. At first, correlation analysis was done for crown openness and regeneration count with the help of Microsoft excel. One-way ANOVA was used to find the significant difference between.

Results

The results indicate that regeneration was affected by crown openness. Crown openness was more in the research plot where there was a smaller number of trees left unharvested. Minimum crown openness was of plot 5 i.e., control plot. This was unharvested plot with more sums of trees than in other 4 research plots.

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Basal area and volume of residual trees within research plots were calculated and analyzed which showed profound relationship between characteristic of residual stand and regeneration. More regeneration was observed on a site with lower volume and basal area and vice versa (Figure 3).

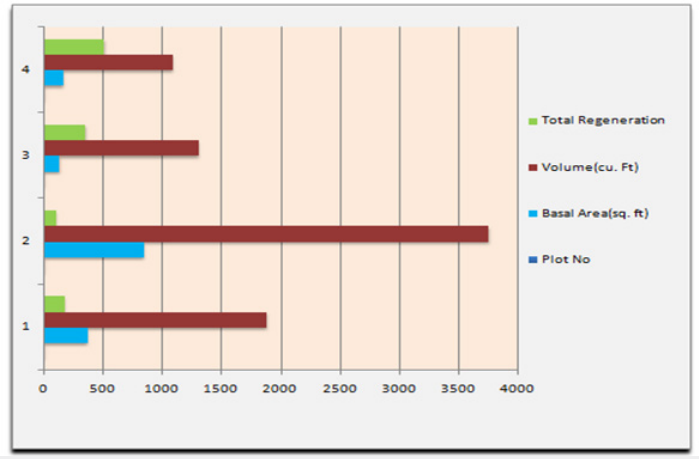

Figure 3: Basal area, stand volume and seedling count.

Status of crown openness

The graph below depicts the crown openness of the research plots. Degree of crown openness differed considerably between research plots ranging from 21% to 71%. Maximum crown openness was seen in plot 4 i.e., Regular Shelterwood system, whereas maximum crown closeness (minimum crown openness) was experienced in plot 5 i.e., Control plot. Crown openness of plot 3 was two times as more as of plot 2. As for the plot 2, it has the second lowest crown openness among five plots (Figure 4).

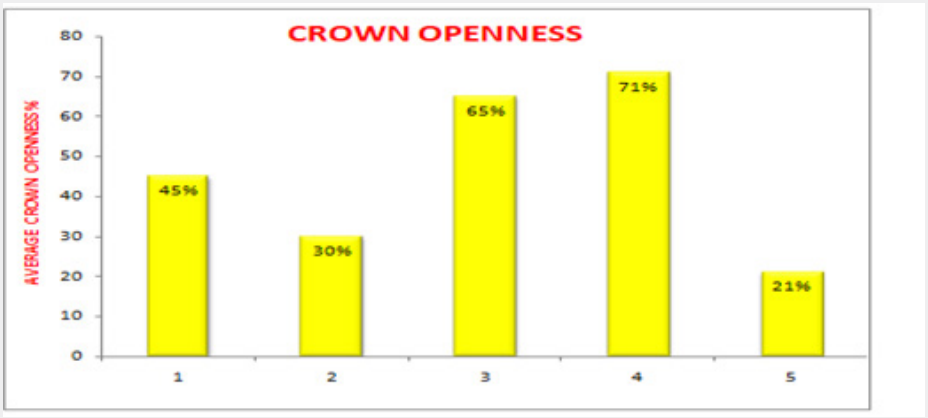

Figure 4: Crown openness% in research Plots.

Status of regeneration

There was noticeable difference of regeneration among Research plots. Plot 4 had a greater number of regenerations; however, plot 5 (control plot) had a smaller number of regenerations. Status of growth and development of regeneration was different between research plots. In Plots 2 & 3 development of seedling was very poor that the maximum height was of only 43cm and 25 cm but in plots 3 & 4 development of seedling was more with maximum height of 180cm and 140cm. Also, the greater number of seedlings were in higher height class for plot 3 & 4. Conversely, lower height class of seedling were in plots 1, 2 & 5. Average height of seedlings in plots 1,2,3,4 & 5 was 23cm, 12cm, 59cm, 56cm & 11cm, respectively (Table 1).

The application of one-way ANOVA test at 5% level of significance showed no significant difference in the regeneration number between sample plots 2&5 and 1&2. While there was significant difference in number of regenerations between the sample plots 1&2, 1&3, 1&4. 1&5, 2&3, 2&4, 3&4 (Table 2).

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Table 1: Regeneration dynamic among research plots.

Plot No	Total Regeneration	Height Class(cm)							Maximum Height(cm)
		<15	16-30	31-45	46-60	61-75	76-90	>90	
1	176	22	79	30	8	4	0	1	115
2	104	77	24	3	0	0	0	0	43
3	355	25	47	79	59	44	28	73	180
4	515	25	61	112	122	83	65	47	140
5	34	27	7	0	0	0	0	0	25

Table 2: Statistical test for regeneration.

Plot	N	Subset for alpha = 0.05			
		1	2	3	4
5	30	1.0333			
2	30	3.4667	3.4667		
1	30		5.1		
3	30			11.6	
4	30				18.0667
Sig.		0.092	0.258	1	1

Table 3: Correlation between Crown openness and Regenerations.

Plot No	Crown Openness(a)	Regeneration(b)	COR (a, b)
1	45	175	0.9144
2	30	104	
3	65	515	
4	71	355	
5	21	34	

Relation of crown openness and regeneration

Crown openness and regeneration data from sample plots showed correlation of 0.9144 between them which is highly correlated (Table 3).

All the data of crown openness and regeneration is displayed in the scattered plot. Pattern of plot suggest that more the crown openness more is the regeneration. Sample points with crown openness 10%-40% had regeneration up to 17 per $1m^2$ whereas sample points with crown openness 50%-80% had regeneration up to 34 per $1m^2$ (Figure 5).

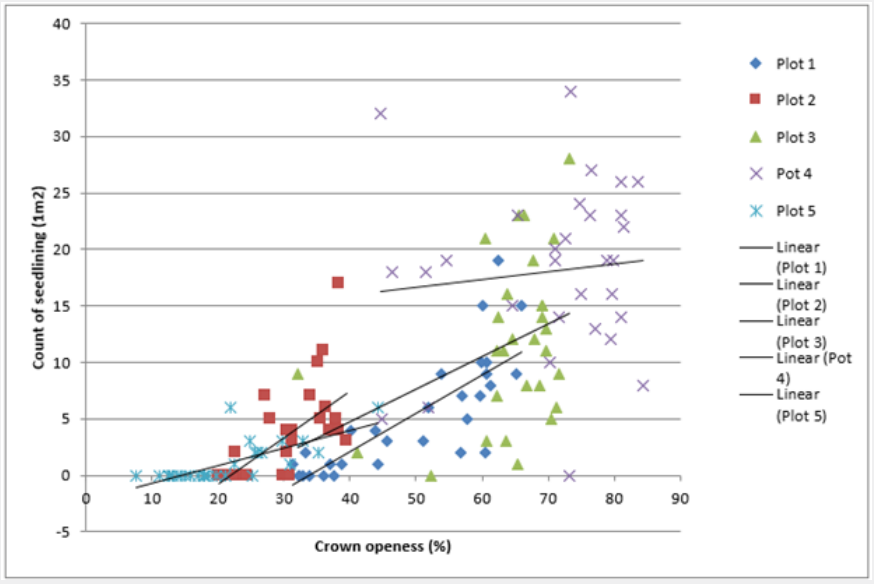

Figure 5: Crown openness percent and regeneration number of each sampling point.

Discussion

The result obtained from the data of extensive fieldwork and analysis shows that the crown openness in pine forest affects the regeneration number and its growth. This relation about the influence of the Canopy gap on the regeneration of pine forest was also mentioned by [14] in his research paper. Gaps on canopy de-

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termine the resources available to regenerating species i.e., more resource will be available in the open canopy than in dense canopy. Van Der Meer & Bongers (1996) also states that "The resources (light, water, and nutrients) available to regenerating species are determined by gap characteristics." This also suggest that more the crown openness more the regeneration growth and development. However, the significant differences are not observed in some plots, like in case of regeneration of plot 1&2 and 2&5 though there was a significant difference in crown openness.

Use of Spherical Densitometer for estimating forest over story is a reliable method which is suggested by the guidelines for measuring carbon stocks in community-managed forests (Subedi et al. 2010). Crown openness data obtained by use of spherical densitometer is 45, 30, 65, 71 for plot 1, 2, 3, 4, 5 respectively which shows the same pattern to the data obtained by Forest Action, EnLiFT project, 3 years ago using fishnet lens, that is 59.39, 45.28, 72.27, and 85.59 for plot 1, 2, 3 & 4 respectively. Seedling is reliable method to assess the regeneration status in absence of sapling stage. Which is also supported DFRS [13]. Regeneration per hectare of the control plot obtained by my field work was nearby the number of regenerations per hectare of forest area mentioned in the Operational plan of Chappani Gadhidanda CF i.e., 14000 per hectare and regeneration is affected by crown openness or says gaps on forest canopy represent opportunities for forest regeneration [3,15-32].

Conclusion

The study shows that crown dynamics has an effect on the regeneration status not only in terms of number but also in terms of their development and survival case. In dense canopy not only grow and development of seedling was in the lower side but also the survival of seeding was least in number. Hence, it is clear that the more the crown openness more the healthy will be regeneration status; however, in case of plots 2&5 and 1&2 crown openness was significantly different but in terms of regeneration they were not significantly different. This indicates that some degree of crown openness is required to affect the regeneration status to be significantly different. Research data suggested the presence of relationship between independent variable crown openness and dependent variable regeneration more than the exact degree of relationship about how much crown openness will favor how many numbers of regeneration and their development.

Canopy openness can enhance the growth and development of regeneration but no only the degree of crown openness should be considered while harvesting. Due to thick numbers of trees in overstory there is always a risk of wind damage and same was the case in my research site where tree was broken and uprooted by wind force. Due to this in absence of overstory protection young seedlings may be exposed towards the harsh environmental conditions. This may reduce their survival ratio. So, not only degree of openness but also the number of tree to no harvest should be taken in consideration particularly in windy region with harsh environment. More research should be carried out to establish the exact relation between degree of crown openness and the number of regeneration and existing forest management should include the appropriate silvicultural treatment to enhance the regeneration status.

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