

Analyzing Forest Management Practice in Different Felling Series: A Case Study from Community Forest of Rupandehi District, Nepal

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Abstract

Scientific Forest management (SciFM) in community forestry emphasizes establishing and growing regeneration by adopting different silvicultural systems. To assess the effectiveness of forest management practices, we examined the regeneration condition and its pattern in the forest with a scientific forest management plan. Data relating to regeneration status and its growth pattern were collected from two community forests using stratified random sampling. The results depicted good regeneration conditions (Seedling > 5000, Sapling > 2000) in all the felling series of both the forest. The number of seedlings and saplings was found highest in the sixth-year felling series (22,000 per ha) in Kanchan CF while it was highest in the fifth-year felling series (35,700 per ha) in the case of Rajapani CF. The forest of both the CF was dominated by Sal (*Shorea robusta*) followed by Asna (*Terminalia alata*) and Karma (*Adina cordifolia*). The number of seedlings per hectare was found higher in the strata with the latest regeneration felling while the number of poles per hectare is found higher in the strata with the oldest regeneration felling in a condition where there was less human pressure. The overall growth pattern of regeneration based on average diameter and an average height of Kanchan CF showed an upward sloping curve with the increase in years after the regeneration felling while that of Rajapani CF showed a slightly irregular curve representing irregular growth of regeneration based on average height. There were altogether 14 and 13 species in Kanchan CF and Rajapani CF respectively where both CF showed a similar degree of species richness and evenness. This research contributes to assessing forest sustainability based on regeneration growth with appropriate management strategies. It recommends the implementation of SciFM with proper monitoring and continuous management practices to enhance the forest's health and growth.

Introduction

Nepal's forests are managed under various management regimes. Community forestry is viewed as the best technique for effective resource management and manipulation in the context of Nepal. It has proven an excellent tool for addressing a forest's basic needs without compromising the health of the forest. Since this management approach put a strong emphasis on safeguarding the forest, the Scientific Forest Management (SciFM) method was developed to address the productive function of the forest. SciFM is the practice of maximizing direct and indirect benefits from the forest through the application of forestry science information based on accurate assessments of forest crop attributes (MFSC, 2014). SciFM divides the entire forest into sections and blocks based on both natural and man-made elements. These compartments divide into felling series, which further divided into several sub-compartments, depending on the silvicultural technique employed (MFSC, 2014). SciFM was developed in Nepal with the purpose of ensuring regenerative growth by age-grading/classes, normal increments, and normal growing stock (Awasthi et al., 2015). It considers the forests' output and productivity as well as the replenishment of its resources, and it helps predict the forest's growth pattern (MFSC, 2014). It helps to control the dynamics of the forest, the pattern of regeneration growth, and the overall productivity of the forest

(Awasthi et al., 2015; Joshi et al., 2018 through regeneration production, where regeneration felling is the central managerial practice (Khanal & Adhikari, 2018).

Regeneration of the forest refers to the establishment or growth of new individual plants. It is regarded as the cornerstone of forestry sustainability (McNabb, 2004). Although various climatic and edaphic factors influence the growth of regeneration, its presence indicates the stability of the plant community (Poudel & Devkota, 2021). The state of the regeneration in each forest indicates the health and vitality of the forest, and a healthy forest promotes the growth of future regeneration (Awasthi et al., 2015). The species of regeneration that present in the forest are very important in determining its composition. The productivity and capacity for regeneration of the forest are determined by the presence of seedlings, saplings, and trees of various age groups (Chauhan et al., 2010). Regeneration is considered a means to objectify the sustainability of forest management based on the forest's productive capacity and biological diversity (Lutze et al., 2004).

Objectives

General objective

The general objective of this study is to analyse the forest management practice through regeneration status and growth patterns in different felling series of the study area.

Specific objectives

Specific objectives of the study are:

- To assess the regeneration status in the study area
- To assess the growth pattern of the regeneration in different felling series
- To analyse the regeneration diversity of the study area.

Materials and Methods

4.1. Study Area

The study was conducted in two community forests located in Rupandehi district based on the year of SciFM plan implementation with the regeneration felling of more than five years. Community forest of Rupandehi district was selected for study as it has been a pioneer district to implement SciFM in Nepal since 2013 (Khanal & Adhikari, 2018).

Kanchan CF and Rajapani CF cover an area of 131.55 ha. and 270.55 ha and is divided into eight blocks for scientific management of the forest as shown in Fig. 1 and Fig. 2. Both the CF are tropical deciduous forest with Sal (*Shorea robusta*) as the dominant species associated with Asna (*Terminalia alata*), Karma (*Adina cordifolia*), Rajbrikshya (*Elaeocarpus sphaericus*), Kutmero (*Litsea monopetala*), Rohini (*Mallotus*

philippensis), Jamun (*Syzygium cumini*), etc. Table 1 shows the general information about the studied CFs.

Table 1
General information about the studied CFs.

Name of CF	Area(ha)	Handed over as CF (year in A.D.)	SciFM implementation year (A.D.)	Management Duration (years)	No. of plots(N)	Forest Type
Kanchan CF	131.55	2009	2013/14	6	19	Natural and Plantation
Rajapani CF	270.55	2001	2013/14	6	20	Natural and Plantation

4.2. Data Collection

For the data collection on regeneration status, stratified random sampling method was used. In this method, total study area was divided into smaller homogenous groups known as strata. Each stratum was formed based on the regeneration felling, in which regeneration felling series function as the strata for data collection. Sample plots were laid out in the study area with the help of fishnet tool in ArcGIS and the GPS coordinates were extracted for each sample plots. Concentric circular plots of radius 1.78m, 2.82m and 5.64m for seedlings, sapling and poles respectively (Aryal et al., 2017) were assigned for data collection as it has the least edge effect and so have least bias.

Table 2
General information about sample plots in different felling series

Felling Series	Kanchan CF		Rajapani CF	
	Area (Ha.)	No. of Sample plots	Area (Ha.)	No. of Sample plots
First-Year	1.22	3	3.16	4
Second-Year	1.43	5	3.50	3
Third-Year	1.45	3	3.49	4
Fourth-Year	1.39	3	3.44	3
Fifth-Year	1.40	3	3.28	2
Sixth-Year	1.37	2	3.33	4
Total	8.26	19	20.2	20

4.2.1. Primary Data

The quadrat method based on stratified random sampling method was used for sampling, Vegetation was divided into three growth stages as poles (dbh > 10cm), sapling (dbh < 10 cm; height > 1.3m) and seedling (height < 1.3m). The dbh and height of the poles was measured along with the count number, height, and average diameter of the sapling (divided into two categories of dbh < 5cm and 5cm < dbh > 10cm) and average collar diameter of seedling to predict the growth pattern and the regeneration status of the study area.

4.2.2. Secondary Data

All relevant articles, journals, newspapers, published and unpublished reports were used for secondary data collection. Operational plans of respective CFs were used to assess the regeneration status before implementation of management practices to predict growth patterns.

4.3. Data Analysis

4.3.1. Regeneration status and growth pattern

The inventory data collected from both CFs was analyzed based on the Forest Resource Information analysis sheet given by the CF Inventory Guideline 2061. Firstly, the total number of seedlings and saplings were computed based on the sample data and the average number per plot was calculated for regeneration. Then the number per hectare was computed based on the formula given by the guideline. For the analysis of pole data, number of poles per plot was calculated from the sample data which is then used to compute number of poles per hectare. The obtained result of regeneration status was then presented in Microsoft Excel using bar diagram and line curves.

The status of regeneration in the study area was compared based on regeneration of species per hectare found in respective felling series. Then the growth pattern of regeneration was analysed based on the diameter and height growth for each year after the regeneration felling for each vegetation strata.

Table 3
Regeneration/ha showing the condition of forest (CF Inventory Guideline, 2061)

Plant Type	Number per hectare		
Seedling	> 5000	2000– 5000	< 2000
Sapling	> 2000	800–2000	< 800
Condition of Forest	Good	Medium	Poor

4.3.2. Regeneration diversity analysis

Regeneration diversity refers to the richness and evenness of variety of species within an area. The species richness refers to the total number of species per unit area while species evenness denotes the distribution of individuals among the species. Evenness is maximum if all species are similar or equal in

number of individuals. Different formulae were used to calculate the diversity index for each felling series as shown in Table 4.

Table 4
Formulae to calculate Diversity indices.

Diversity Index	Formula
Shannon Weiner Diversity Index(H')	$H' = -\sum_{i=1}^s (pi) (\ln pi), \text{ where } s = \text{total number of species in sample}$ <i>pi</i> = proportion of all individuals of species <i>i</i>
Simpson's Index (C)	$C = \sum_{i=1}^s (pi)^2 ; 0 < C < 1$
Species richness index (d)	$D = \frac{1}{\sum_{i=1}^s p_i^2}$ where <i>N</i> = number of individuals of all species
Equitability or evenness index (e)	$e = \frac{H'}{\ln s}$ It ranges from 0(not even) to 1(completely even)

Results

5.1. Results

5.1.1. Regeneration Status

The regeneration status of species on both the CFs were studied based on the number of saplings and seedlings per ha in each sample plot. According to the number of seedlings and saplings of different species in the sample plots of different felling series, all the felling series of both the forests was dominated by *Shorea robusta*.

Kanchan Community Forest

The total number of seedlings (17,000/ha) and saplings (5,000/ha) was found to be highest in the sixth year Felling Series in which *Shorea robusta* has the highest number of seedlings (13,000) and saplings (5,000) per ha. Similarly, second year and third year felling make up the second and third highest number of regenerations per ha respectively which is followed by fifth- and first-year felling series.

The fourth-year felling series with least number of seedlings (11,333/ha) and saplings (3,867/ha) with *Shorea robusta* as the dominant species followed by *A. cordifolia*.

Figure 3 presents the summary of regeneration status in different felling series. The overall regeneration status was in good condition as per the CF Inventory Guidelines 2061 as number of seedling and

saplings exceeded 5,000 and 2,000 respectively.

Rajapani Community Forest

The study found that the highest number of seedlings (22,500/ha) and saplings (13,200/ha) in Rajapani CF occurred in the fifth year Felling Series, followed by the second-year felling series, with the third, sixth, and first year felling series having progressively fewer regenerations per hectare.

The fourth-year felling series had the lowest number of seedlings (10,000/ha) and saplings (2,400/ha) and was dominated by *Shorea robusta* followed by *Sissoo*. The regeneration status in different felling series in Rajapani CF is presented in Fig. 4 and is in good condition according to the regeneration criteria set out in CF Inventory Guidelines 2061.

5.1.2. Growth Pattern of regeneration

5.1.2.1. Kanchan CF

There is slight increment in the average height of seedlings with increase in the years after regeneration felling while remarkable increment in average height of sapling (dbh < 5cm) can be seen as shown in the Fig. 5. Similarly, there is slight increment in the average diameter growth of the seedling and sapling with the increment in the years after regeneration felling as shown in the Fig. 6. It shows that there is growth in average diameter and height of seedling and sapling with the years of stand after regeneration felling.

5.1.2.2. Rajapani CF

The growth of regeneration in Rajapani CF is characterized by an irregular pattern of average height growth with the years after regeneration felling, as illustrated in Fig. 7. However, on average, there is an upward trend in the growth pattern of seedlings based on average height with increasing years after regeneration felling. In terms of average diameter, there is an increase in regeneration growth up to the fifth year stand from the third year regeneration, after which there is a slight decline with successive years of regeneration felling. The overall growth pattern of regeneration based on diameter indicates an upward trend, with an increase in average diameter observed as the years after regeneration felling increase, as shown in Fig. 8.

5.1.3. Regeneration Diversity in different felling series

5.1.3.1. Kanchan CF

The total number of the tree species found in First, Second, Third, Fourth, Fifth- and Sixth-year felling series (FS) are 6, 6, 6, 4, 6 and 4, respectively. The study showed the highest Shannon Weiner's index in Fourth year FS i.e., higher degree of species richness and evenness found in fourth year felling than other felling series, while Fifth year FS showed lowest Shannon Weiner Index. Thus, the concentration of

dominance of fourth year felling series was found significantly lower as compared to other FS, revealing the higher diversity within the species and fifth year felling series with lower diversity within species and *S. robusta* to be dominated in the study area as shown in Table 5. Similarly, fourth year felling series has higher value of evenness index supporting the result of Shannon Weiner index, which means fourth year felling series has more even number of species compared to other felling series.

Table 5
Felling series-wise diversity indices of Kanchan CF

Felling Series	H'	C	D	e
First year FS (071/72)	0.52	0.79	1.14	0.29
Second year FS (072/73)	0.34	0.87	0.995	0.19
Third year FS (073/74)	0.56	0.76	1.11	0.31
Fourth year FS (074/75)	0.82	0.53	0.72	0.59
Fifth year FS (075/76)	0.33	0.88	1.36	0.18
Sixth year FS (076/77)	0.68	0.67	0.72	0.49
Note: H': Shannon Weiner's Index, C: Simpson's Dominance Index, D: Species Richness Index, e: Equitability or evenness Index				

5.1.3.1. Rajapani CF

The study examined the tree species present in six different felling series - First, Second, Third, Fourth, Fifth, and Sixth-year FS, and found that the highest degree of species richness and evenness was observed in the First-year FS, as indicated by the Shannon Weiner index. Conversely, the Second and Fifth-year FS had the lowest Shannon Weiner index, which revealed a higher concentration of dominance and lower species diversity, with *S. robusta* being the dominant species in the study area, as shown in Table 6. Additionally, the evenness index in the First-year FS was higher than in other FS, indicating a more even distribution of species in the First-year FS compared to the other felling series.

Table 6
Felling series-wise diversity indices of Rajapani CF

Felling Series	H'	C	D	e
First year FS (071/72)	0.83	0.60	0.94	0.51
Second year FS (072/73)	0.31	0.87	0.63	0.22
Third year FS (073/74)	0.59	0.71	0.84	0.36
Fourth year FS (074/75)	0.79	0.64	1.29	0.44
Fifth year FS (075/76)	0.31	0.86	0.42	0.28
Sixth year FS (076/77)	0.80	0.62	0.89	0.50

Discussion

This study sought information about the regeneration status, growth trend and plant diversity in two community forests i.e., Kanchan CF and Rajapani CF of Rupandehi district. This study discovered that implementing SciFM in community forests retains the forest's potential through regeneration establishment. On average, there were 10,600 seedling per ha, 3,640 saplings per ha and 176 poles per ha in Kanchan CF and 11,142 seedling per ha, 1,885 saplings per ha and 232 poles per ha in Rajapani CF before the implementation of SciFM. There is the increment in number of seedlings (14,745 per ha), sapling (4,940 per ha) and poles (551 per ha) in Kanchan CF and seedlings (15,458 per ha), sapling (5,727 per ha) and poles (251 per ha) in Rajapani similar to the results of (Aryal et al., 2021; Awasthi et al., 2015; Khatri et al., 2021). Baral et al., (2020) found that there is significance difference in regeneration number due to canopy cover, i.e., higher number of regenerations in open canopy. Similarly, Awasthi et al., (2020) found that interventions under the SciFM increased the seedling density of *Shorea robusta* since canopy opening and creation of gaps in forest supports regeneration growth. The overall number of seedling and sapling in both CF was found to be higher, it could be due to the regeneration felling and canopy open due different management practices applied in different felling series as suggested by the SciFM guideline. The varying intensity of management interventions, cleaning activities, and invasive species invasion in the various felling sites causes the variations in regeneration growth in different felling series. The overall regeneration status of all the felling series was in good condition as the number of seedlings and saplings exceeded 5,000 and 2,000 respectively as per CF Inventory Guidelines 2061.

This study demonstrates that the use of the SciFM technique in managing forest regeneration in Community Forestry (CF) leads to an increase in regeneration growth, particularly in the most recent felling series where the open canopy cover facilitates the growth of light-demanding species such as *Shorea robusta*. The silvicultural system and post-harvest operations implemented in SciFM also contribute to an increase in seedling density within the felling series. As the number of years after regeneration felling increases, the average diameter and height of regeneration in both CFs show an upward trend, indicating progressive growth if other factors remain constant. Older stands have higher sapling density due to post-harvesting practices that remove unwanted species and promote the growth of seedlings into saplings. However, felling series with lower site quality and high anthropogenic pressure, particularly those located near human settlements, experience a sudden decline in seedling and sapling density, highlighting the negative impact of human activities on regeneration growth.

There were altogether 14 and 13 tree species found in Kanchan CF and Rajapani CF. Sapkota et al., (2010) found decline in the tree diversity while dominance of *S. robusta* increases linearly with increasing disturbance intensity in Nepalese *Sal* Forest, similar to our study. In general, the overall diversity in the forest with SciFM approach decreases due to management practices oriented to promote desired species as suggested by (Awasthi et al., 2015; Khatri et al., 2021). Within the study area, the higher value of Shannon Weiner's Index in fourth year and first year felling series of Kanchan CF and of Rajapani CF respectively indicates the higher degree of species richness and evenness in those felling series. This is supported by the lower value of Simpson's Dominance index and higher value of Equitability or Evenness

Index of those felling series. This difference in diversity within the felling series may be contributed by different intensity of management interventions along with other anthropogenic activities like increased grazing and trampling by domesticated cattle and increased human pressure in peripheral strata of forest near human settlement.

Conclusion

This study was based on Community Forests of Rupandehi district adopting Scientific Forest Management approach to analyze the regeneration status and growth pattern in different felling series along with plant diversity in each felling series. We found that the density of seedlings increased significantly because of silvicultural practices such regeneration felling and subsequent post-harvesting activities. Similarly, it was observed that management practices had a substantial impact on suppressing seedlings of undesirable species as well as the development of the retained seedlings into saplings. There is higher number of regenerations in latest felling series and higher number of poles in old stand indicating progressive development of regeneration in each felling series. The overall regeneration status of all the felling series was in good condition as the number of seedlings and saplings exceeded 5,000 and 2,000 respectively as per CF Inventory Guidelines 2061. Due to some external factors like anthropogenic pressure influencing the growth pattern of regeneration in some felling series. After considering the effects of the silvicultural interventions used in managing forest, management planners and practitioners should now concentrate on intermediate levels of disturbance to help balance the effects of management on species diversity and overly dominant single species.

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Figures

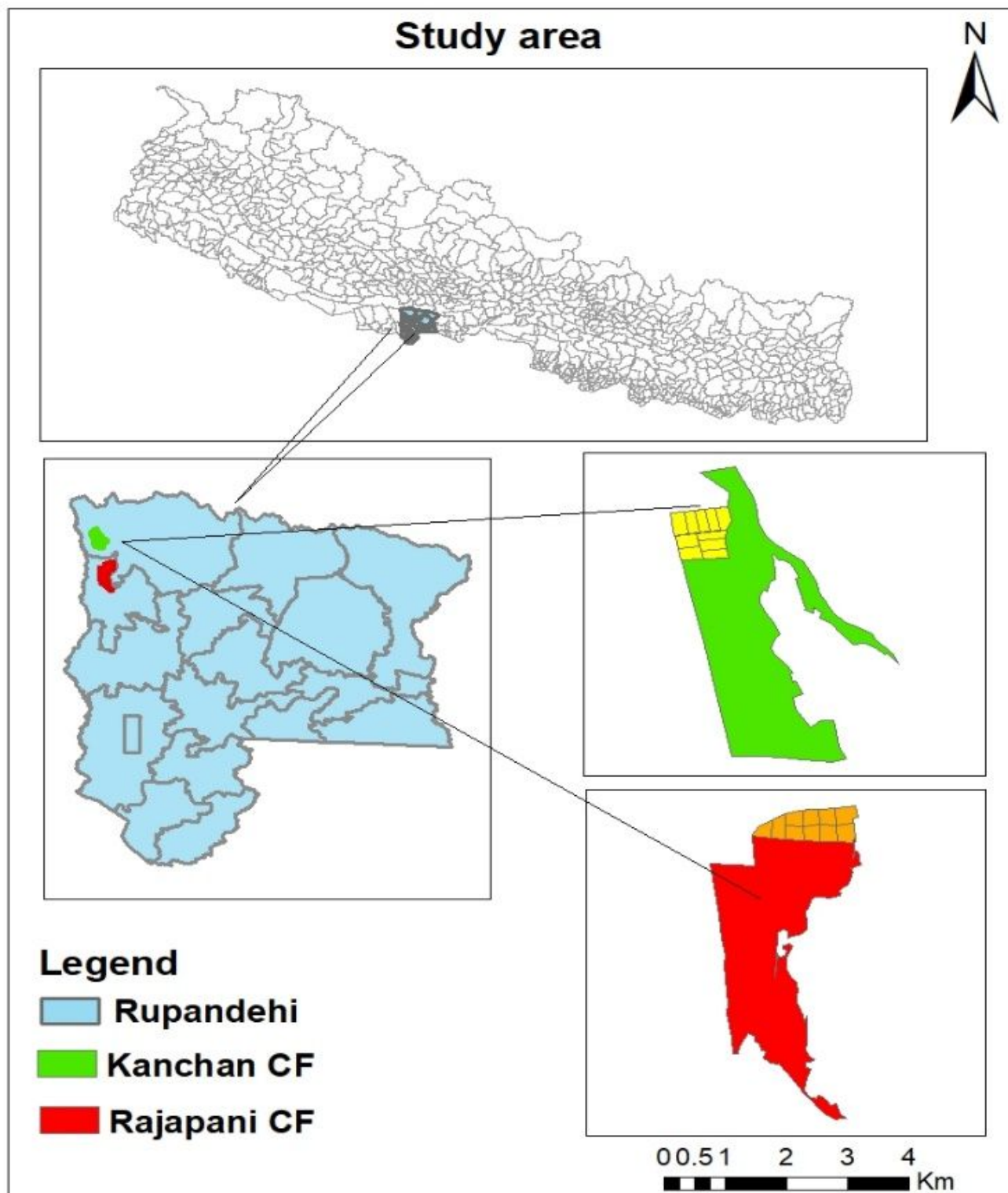


Figure 1

Map showing Kanchan CF and Rajapani CF

Felling Series

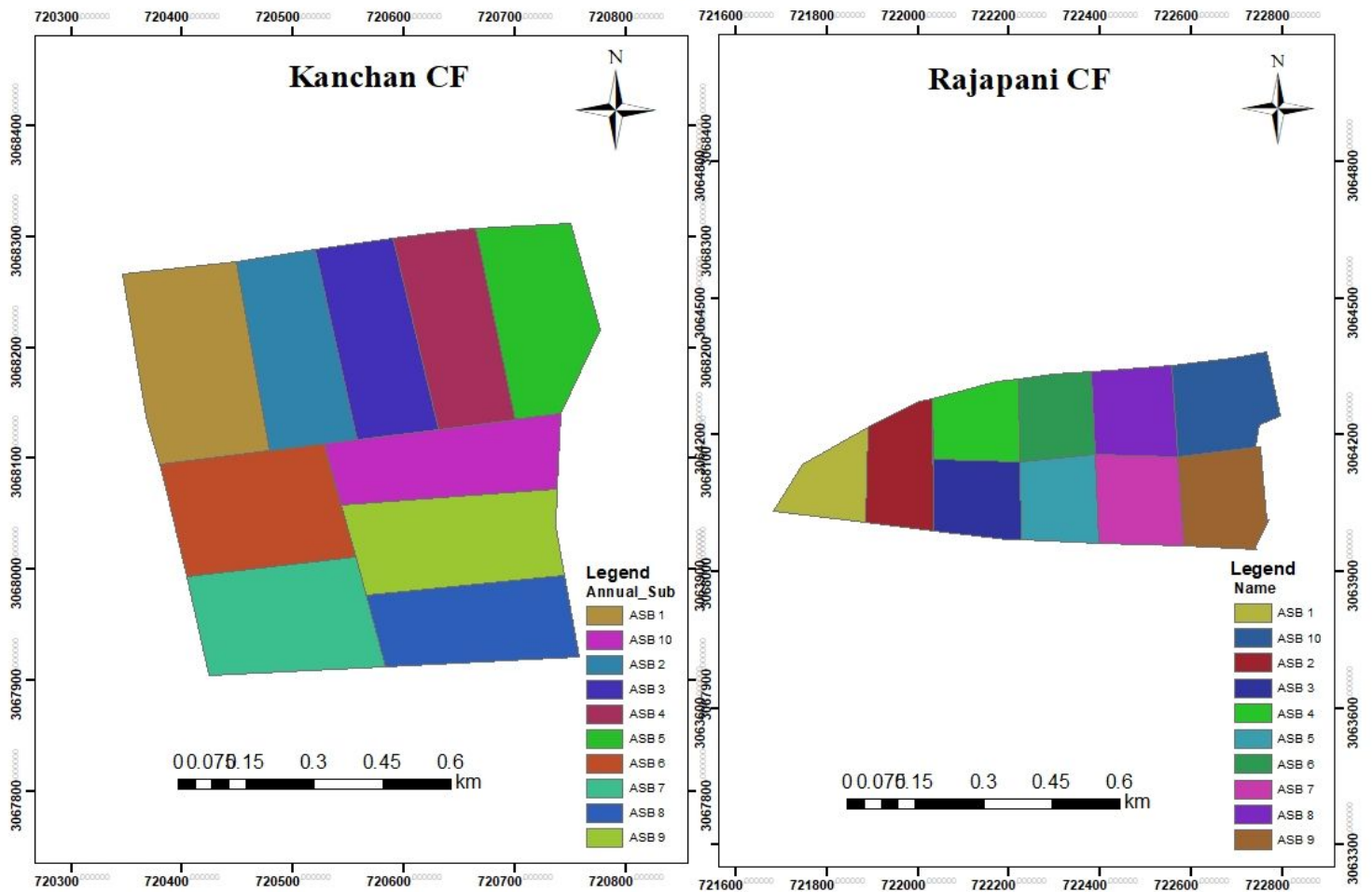


Figure 2

Map showing Felling series of Kanchan and Rajapani CF

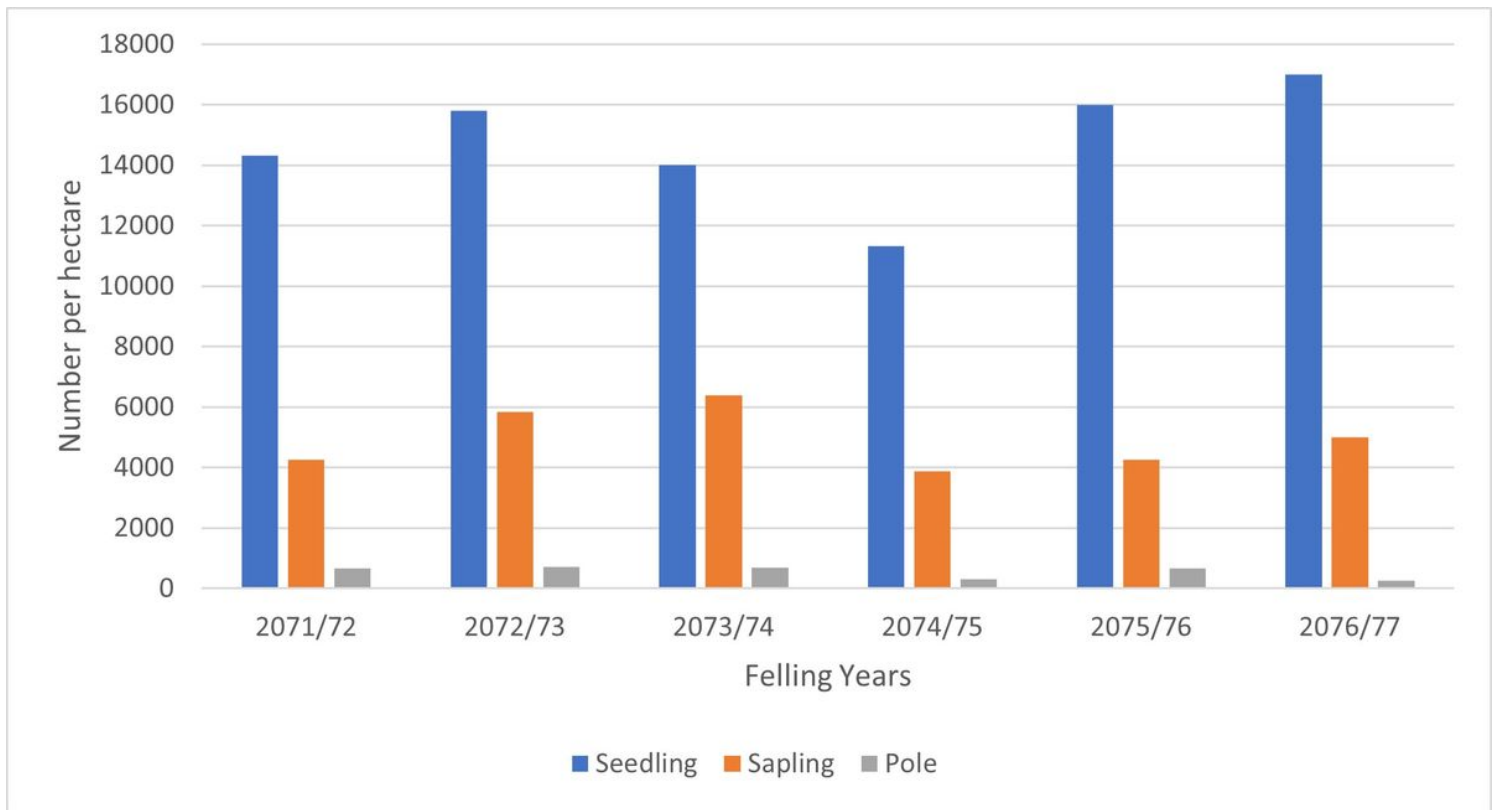


Figure 3
Regeneration status in each felling series of Kanchan CF

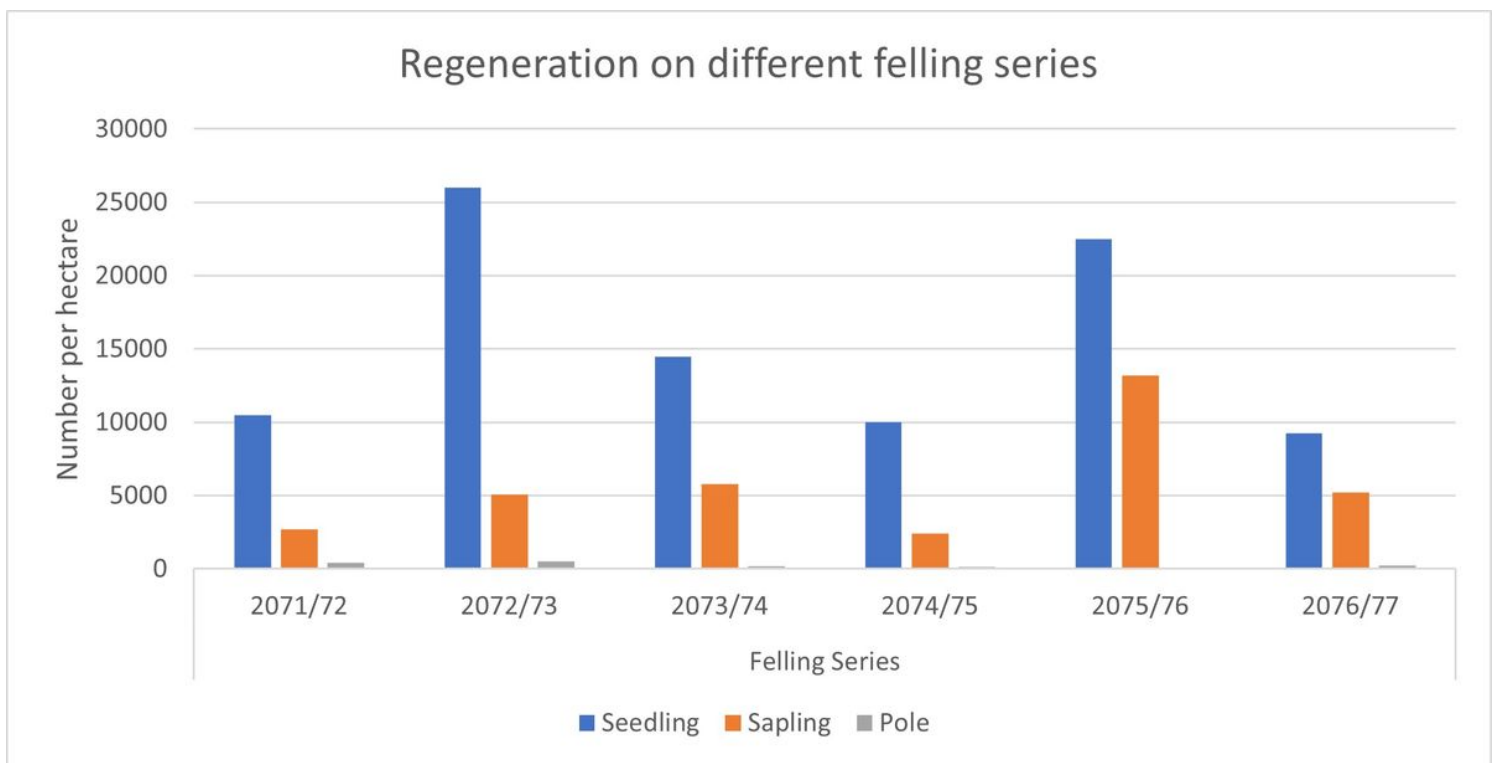


Figure 4

Regeneration status of different felling series of Rajapani CF

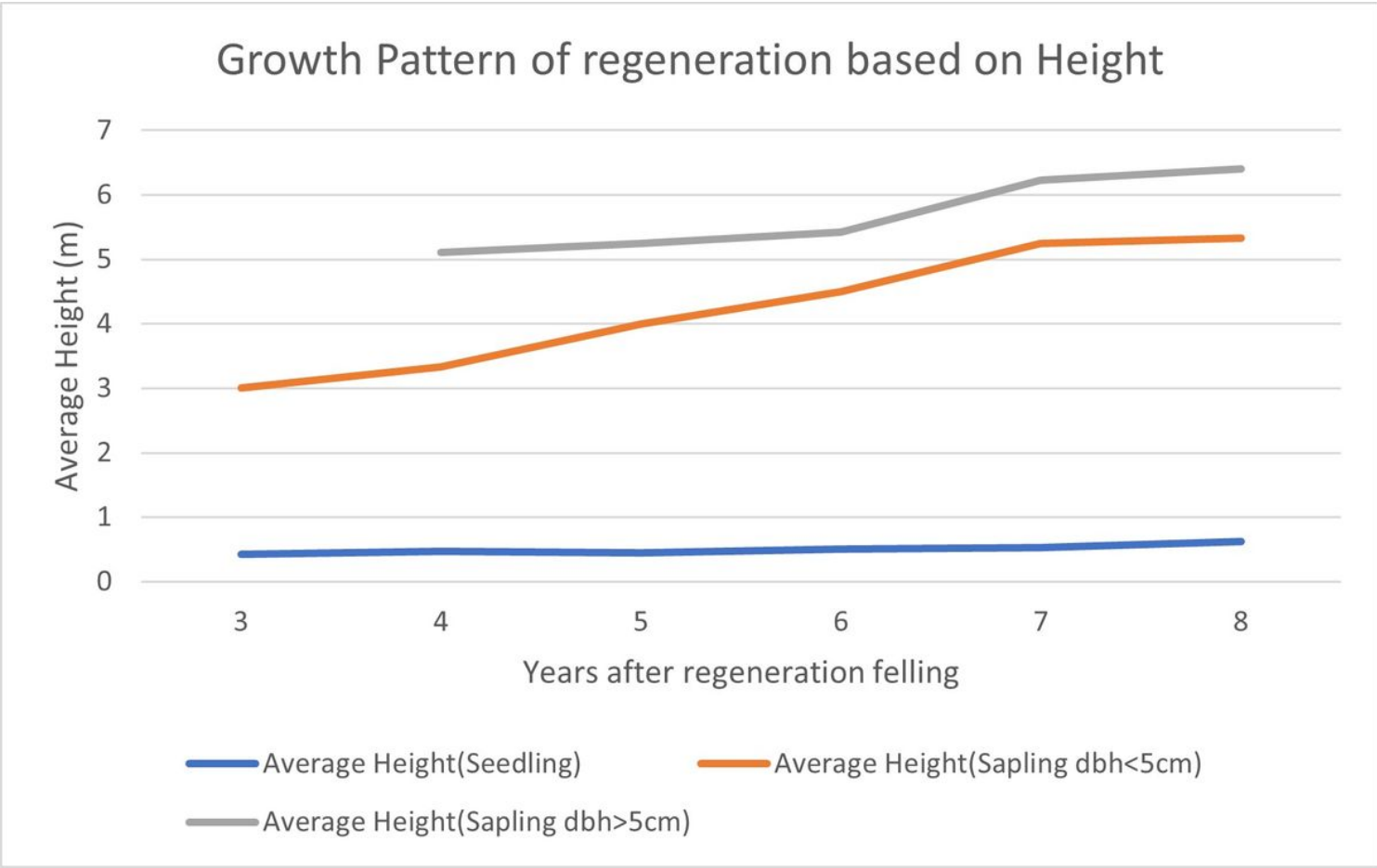


Figure 5

Growth Pattern of regeneration based on Height of Kanchan CF

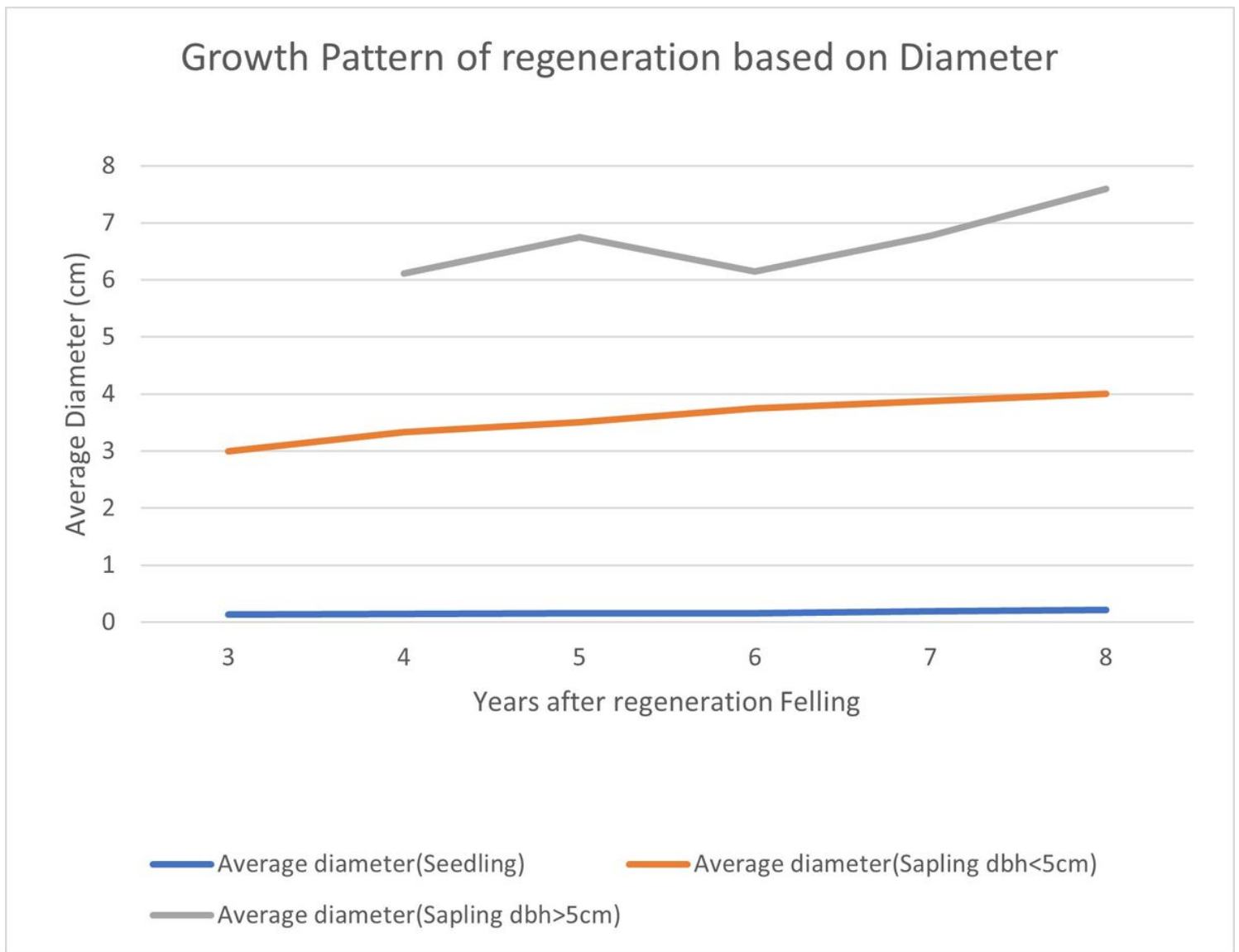


Figure 6

Growth Pattern of regeneration based on Diameter of Kanchan CF

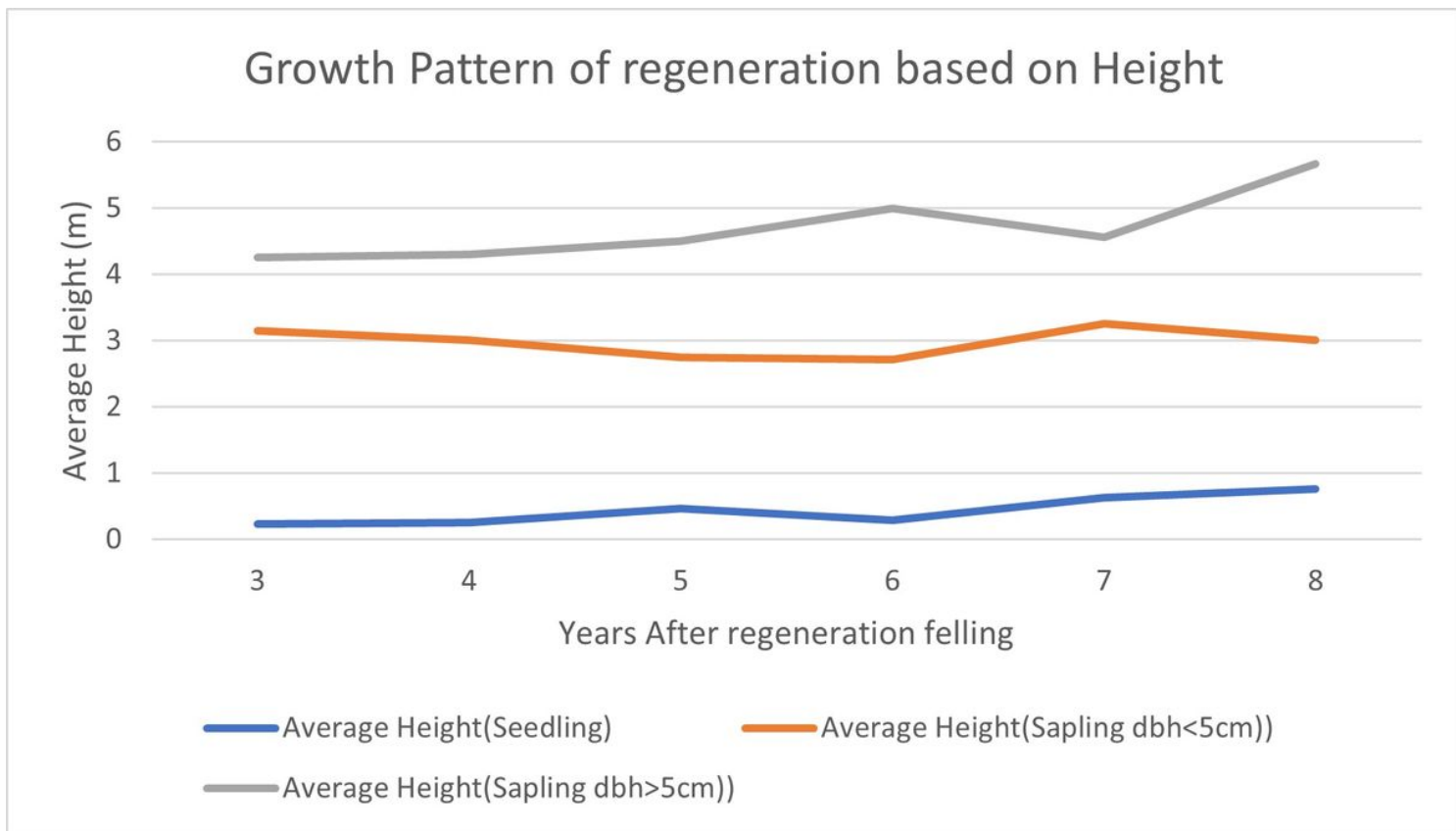


Figure 7

Growth Pattern of regeneration based on Height of Rajapani CF

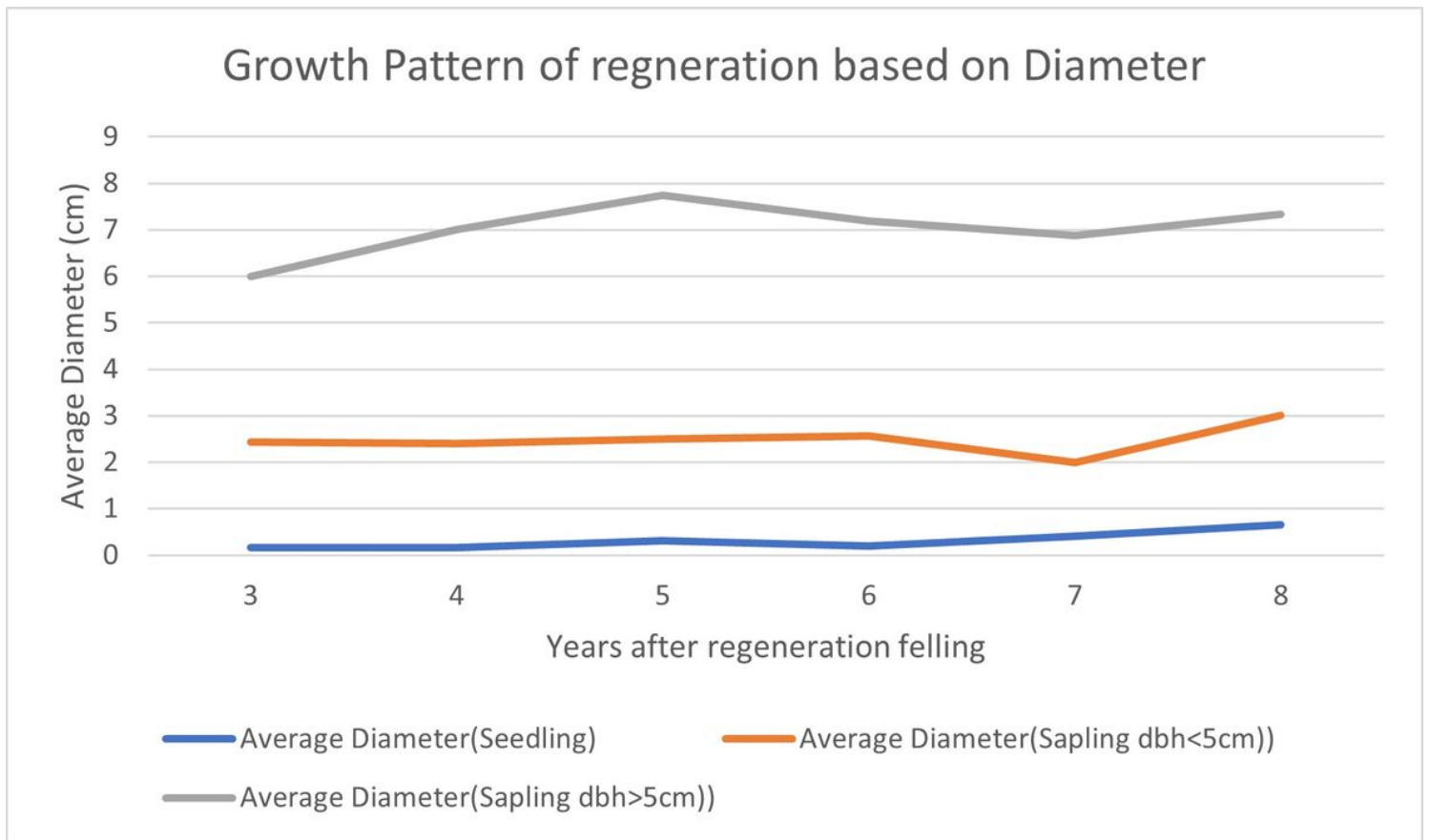


Figure 8

Growth Pattern of regeneration based on Diameter of Rajapani CF