Assessment of Productivity and Profitability through Scientific Forest Management in Sal (*Shorea robusta*) Forest of Nepal: A Case Study from Patela Community Forest, Kailali District, Nepal

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Abstract: Scientific forest management (SciFM) ensures improved productivity and healthy forests that are crucial for the economic development and prosperity of forest-dependent country like Nepal. This study analyzes the effects of the silvicultural intervention on the regeneration of Sal (*Shorea robusta*), plant species diversity, and income through the flow of forest products in the Patela Community Forest in Kailali District of Nepal, where Sal (*S. robusta*) forest has been managed under an Irregular Shelterwood System with 80 years of the rotation period since fiscal year 2017/18. The vegetation sampling was done by the quadrat method based on the principle of stratified random sampling from the managed and unmanaged parts of the forest. The climate based site productivity was analyzed. The profitability of scientific forest management was analyzed by income and cost incurred in managing the forest. The study revealed the promising regeneration of *S. robusta* in the managed areas compared to the unmanaged area. The silvicultural intervention had a significant negative effect on plant diversity showing an increase in the concentration of dominance of *S. robusta*. An implementation of SciFM plan generated a total net benefit of 187,000 US$ in the last 2017/18, and 2018/19 fiscal years. This study recommends existing natural forests to be managed based on sound silvicultural principles to improve the degrading nature of the productive forest that can generate revenue for the country and opportunity for community development.

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Introduction

The concept of Scientific Forest Management (SciFM) is not new, as it dates back to the late eighteenth century in Germany, which has later been adopted by several training institutions and forest bureaucracies throughout the world (Rutt et al. 2015; Khanal and Adhikari 2018). In Nepal, SciFM approach was first introduced to the lowland Terai region in 2010. The essentiality of SciFM is the statistically sound forest inventories that determine the growing stocks as well as annual increment with sufficient accuracy to ensure that harvesting does not exceed the re-growth over longer-term while maintaining environmental services, such as erosion control, watershed protection, wind protection, species habitat and carbon storage (Rutt et al. 2015). The original scope of SciFM in sustainable timber production and meeting economic objectives has since then widened to include social, cultural, and environmental aspects (FAO 2016).

The government of Nepal has been making efforts to manage the forest of lowlands of Nepal scientifically for economic growth of the nation as well as for benefit of local people. For example, the government initiated managing productive forest of Terai by preparing Operational Forest Management Plan (OFMPs) in the 1990s; similarly, SciFM guidelines were developed in 2014 and endorsed for the promotion of silviculture based sustainable forest management in Forest Policy (2015 and 2019) and also in 15th Five-year National Periodic Plan (2019/20-2023/24) for proper implementation of SciFM, especially focusing on Sal and Mixed hardwood forests under the collaborative and community forest management systems of the Terai and Mid-hills regions of Nepal. The government has clearly defined SciFM as an application of appropriate silviculture systems and forest management principles through the design of systematic compartments of fixed rotation age. This follows primarily the Irregular Shelterwood Silvicultural System with very high-intensity logging, leaving behind 15-30 mature mother trees per hectare (DoF 2014). The vision of the government outlined as "Forestry for Prosperity" laid the policy foundation for SciFM as one of the four key pillars of prosperity (Poudel 2018; Poudyal et al. 2019).

Nepal has experienced a tremendous loss of foregone benefits from the forest as a result of protection oriented forest management neglecting scientific and silviculture based active forest management (Subedi 2011; Banjade et al. 2012; Poudel 2018). For example, the country is losing annual revenue ranging from 19.12 to 38.62 billion rupees; attributed to the protection oriented management, low production, and hence unsustainable management of forest (Subedi 2011; MFSC 2016). Similarly, the steady decline of the Terai forest during 2001-2010 and 1991-2010, with 0.44% and 0.40% loss per year, respectively, indicates that forest management practices are not sustainable (DFRS 2015). Besides, the demand and supply of timber resources are not still well-balanced in the context of Nepal, stimulating for illegal logging and timber smuggling (Subedi 2011; NFA 2012). As such, the utmost need for scientific and silvicultural intervention at the policy and field-level was realized to promote regeneration in the old-growth forest and ensure replacement of old stock with a

new one in the future ensuring good future productivity and profitability. SciFM is an emerging and popular approach of Nepal for managing existing productive forests based on silvicultural intervention, as it follows a silvicultural system and helps in maintaining better forest health and vitality as well as improving the sustainable flow of forest products, environmental services, and revenues for the nation (Awasthi et al. 2015; Khanal and Adhikari 2018; Awasthi et al. 2020).

The regeneration status indicates the health and vitality of the forest and a healthy forest ensures good future regeneration (Awasthi et al. 2015). Moreover, the natural regeneration of *S. robusta* is complex and faces baffling problems (Chauhan et al. 2008), mostly arising due to by climate (light intensity), soil (moisture), seeds, and biotic factors (Singh et al. 1987; Tyagi et al. 2011) and the Sal forest is degrading day by day because of their economic significance (Sapkota et al. 2009). Maintaining the productive capacity and biological diversity of any forest area is an important criterion for sustainable forest management that can be predicted by measuring and analyzing the regeneration (Lutze et al. 2004). The productive character and dynamics of the forest are determined by the presence of different age-group and diversity in seedling, sapling, and tree (Chauhan et al. 2008; Awasthi et al. 2020). The forest regeneration will guarantee its future to produce wood and other forest service continuously; we need permanence in productivity of the forest. To be silviculturally sustainable, forest management must ensure good regeneration; maintain proper age classes or age gradation, and normal growing stock and hence normal increment (Subedi 2011).

Forest area covers 44.74% of the total area of Nepal, almost half of the land area (FRA/DFRS 2014). Scientific management and proper utilization of these resources are the utmost and prominent for the economic development of the country. But, in reality, the protection oriented forest management in Nepal is unable to address the timber and fuelwood demand, which results in illegal felling and smuggling of wood, which in turn has been driving degradation and loss of forest resources. Since SciFM in Nepal aims to promote productive species (viz. Sal in Terai and Pinus in hills) for meeting high timber demand and incorporates harvesting of those species as part of the silvicultural intervention, the study against these harvesting interventions is significant and crucial for further replicating the program based on income-cost incurred, quality and quantity of timber and firewood, employment generated and ensuring benefits for future generations by establishing sound forest condition. Various studies on Sal attempted to focus mainly on regeneration status and biodiversity. This study aims to analyze the potential and growth performance of the early establishment of regeneration as well as revenue generated against established silvicultural intervention in the Sal forest of the country. Therefore, this study intends to assess the effectiveness of silvicultural operation as adopted by the government of Nepal, especially with regard to the regeneration of highly valuable Sal forest and maintaining biodiversity as well as optimization of forest income through the flow of forest resources in the forest management scenario of Nepal.

Materials and Methods

Study Area

The study was carried out in the Patela Community Forest (CF), located in the Dhangadhi sub-metropolitan city of Kailali district, Sudurpaschim province, Nepal (Figure 1). Kailali district extends from $28^022'$ N to $29^005'$ N latitude and $80^030'$ E to $80^018'$ E longitude, covering an area of 3235 km², of which 40% falls within the plain Terai and the rest in the Chure hill range. The climate of the district varies from tropical to sub-tropical with altitude ranging from 109 m to 1950 m from the mean sea level. The average temperature ranges from 5^0C in winter to 43^0C in autumn with an average annual precipitation of 1840 mm (DDC 2015). The total area of CF is 207.05 ha dominated by Sal (*S. robusta*). Other species include Asna (*Terminalia tomentosa*), Banjhi (*Anogeissus latifolia*), Karma (*Adina cordifolia*), and Jamun (*Syzygiumcumini*). It was handed over to 98 households with 585 people for management in 2009, while SciFM in this CF was implemented from the fiscal year 2017/18. The forest has been managed under an Irregular Shelterwood System, a well prescribed silvicultural system by SciFM guideline, 2014. Irregular shelterwood system is a trade-off between the Shelterwood Group System and the group selection system (Parkash and Khanna 1979). The whole forest area has been divided into 8 periodic blocks (C1SCs) for the management of Sal forest with a 10-years regeneration period and an 80-years rotation period. The area control method of yield regulation has been followed. Hence, each periodic block has been sub-divided into 10 annual sub-blocks of equal area (2.14 ha), where regeneration felling activities are carried out each year (PCFMOP 2017).
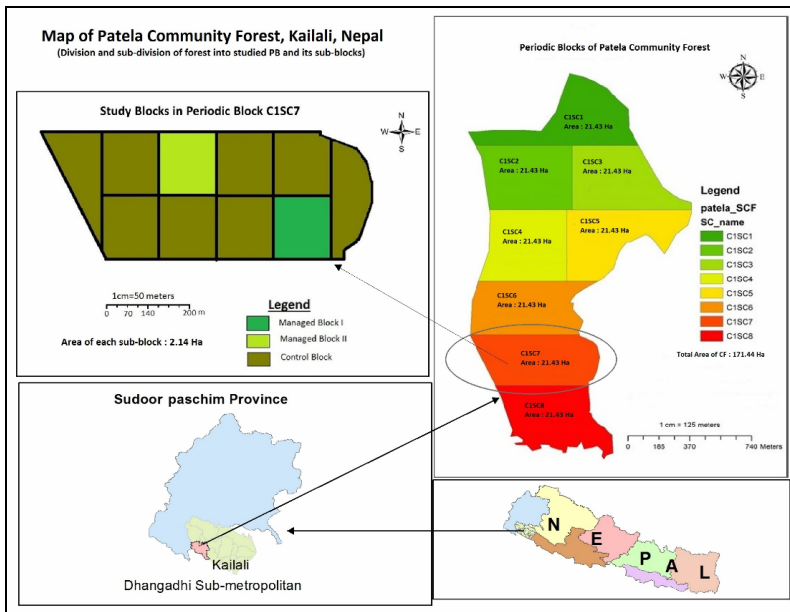

Figure 1: Location map of the study area

The two annual sub-blocks out of 10 in periodic block, C1SC7 were managed through regeneration felling and post-harvest operation until the data collection time of this study. The annual sub-blocks (hereafter "managed block I", first-year stand; "managed block II", second-year stand) were selected as managed blocks (regulated/regeneration felling), while the other 8 annual sub-blocks, within the periodic block, C1SC7, where there was no intervention made, were considered as an unmanaged block (hereafter "control block"). All the annual sub-blocks have an equal area of 2.14 ha, thus, the areas of the managed block I and II were 2.14 ha each, whereas the area of unmanaged blocks (with 8 annual sub-blocks) was 17.12 ha (PCFMOP 2017).

Data Collection

Biophysical Data

The quadrat method was used for vegetative samplings following Mishra (1968) and Basyal et al. (2011). Individual tree species were divided into three growth stages as a tree (dbh>10 cm), sapling (dbh<10 cm; height >1.3 m), and seedling (height <1.3 m). The quadrants of 10 m×10 m were laid out in the study area for trees based on stratified random sampling techniques with the help of ArcGIS 10 and each quadrate was divided into four equal (5 m×5 m size) sub-quadrates from the center and two opposite sub-quadrates used for studying saplings and seedlings, as determined by species-area curve method (Mishra 1968). The height and dbh of tree and sapling were measured using Abney's level and Diameter tape, and crown cover (%) with a densiometer in each sampling unit. Data were collected from September to October in 2019. As the size of managed and control blocks vary, altogether, 10 and 30 sample quadrates were studied from two managed and, control blocks respectively with 2.33% sampling intensity for each managed block (2.14 ha) and 1.75% for the unmanaged block (17.12 ha), based on the nature of the forest and the objective of the study. In addition, meteorological data (temperature and precipitation) were collected for calculating the CVP index of the site from the Department of Hydrology and Meteorology (DHM 2017), Nepal.

Socio-Economic Data

The flow of forest products, income, and expenditure trends were collected from annual and audit reports of CFUG. Collected data were also triangulated through discussions with committee members, and office staff of the CFUG and Division Forest Office, Kailali.

Data Analysis

The plant community composition both in the managed and unmanaged blocks was calculated by Importance Value Index (%) determining density (Individual per hectare, Ind/ha), basal area (m^2), and frequency (%) for each species, adopted by Mueller-Dombois and Ellenberg (1974). Similarly, plant diversity in the managed and unmanaged blocks was calculated using Shannon Wiener's Index, Simpson's Dominance Index, Margalef's Species Richness Index, Equitability or Evenness

Index, and Jaccard's Similarity Index which exclude herbs or climber layers. These indices were calculated using:

Importance Value Index (IVI) = Relative Frequency + Relative Basal Area + Relative Density,

Shannon Wiener's Index (H′) = - $\sum_{i=1}^{s}$ (pi)(In Pi),

Simpson's index of dominance (C) = $\sum_{i=1}^{s}$ (pi)^2,

Margalef's Species Richness Index (S) = $\dfrac{(s-1)}{InN}$,

Equitability or Evenness Index (E) = $\dfrac{H'}{Ins}$, and

Jaccard's Similarity Index, JI = $\dfrac{c}{a+b+c}$

where, s is number of species, N is total number of individuals of species, pi is proportion of all individuals that are of species 'i', c is common species in two community, a=species only found in one community and b is species only found in another community.

The ratio of abundance to frequency distribution was considered regular if it was less than 0.025, random if it was within 0.025-0.05, and contagious if it was over 0.05 (Whitford 1949). Moreover, the potential productivity of the study site was calculated by the productivity function given by Paterson's CVP index (Paterson 1956):

CVP index = $\dfrac{Tv \times P \times G \times E}{Ta \times 12 \times 100}$

where, Tv is the mean maximum temperature (^{0}C),

Ta is difference between mean maximum and mean minimum temperature (^{0}C),

P is the mean annual precipitation (mm),

G is growing season in months,

E is the evapotranspiration intensity based on location (i.e. latitude).

Data were analyzed by descriptive (mean, frequency, standard error) as well as inferential statistics (One way ANOVA, post-hoc LSD, Pearson's correlation) through SPSS software.

Results and Discussion

Results

Species Composition and Distribution Pattern

The total numbers of plant species recorded were 10 and 13 in the managed blocks (I and II, respectively) and 23 in the control block. The *S. robusta* was found to be the dominant species with IVI values of 205.76, 128.67 in managed blocks, and 155.83 in control block, while Asna (*Terminalia tomentosa*) was found to be co-dominant species with IVI values of 23, 80, and 38, respectively in all managed blocks and control block. The dominance and distribution pattern of tree species in managed blocks I and II and the control block is shown in Figure 2. The numbers of plant species exhibiting contagious distribution in managed blocks I and II, and control block were 8, 5, and 18 respectively. The ratio of abundance to the frequency of tree species that was greater than 0.05 showed a clumped (contagious) pattern of species distribution, observed comparatively lower in all species of managed block II.
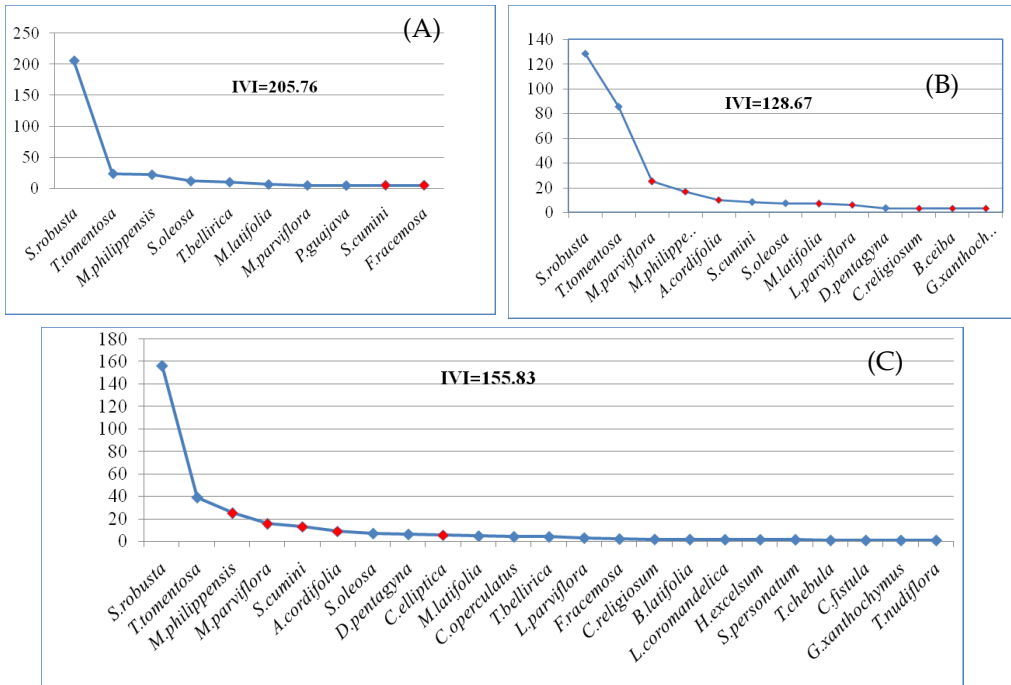
Figure 2: Dominance diversity curve in (A) Managed block I; (B) Managed block II; and (C) Control block (Blue and red dots represent contagious and randomly distributed species respectively)

Plant Species Diversity

Species Richness, Diversity, Evenness and Dominance

The species diversity, concentration of dominance, evenness, and richness index in studied blocks are shown in Table 1. There is low mean Shannon Weiner's Index in the managed block as compared to that in the control block of the forest. Species diversity is generally found inversely related to the concentration of dominance/Simpson's dominance index. Thus, the mean value of the concentration of the dominance of managed blocks I and II was found higher (0.66 and 0.58, respectively) than the control block (0.39) due to lower diversity within the species, and depicting *S. robusta* dominating species in the managed stands. Based on one-way ANOVA, the mean value of the Shannon-Weiner index, Simpson's concentration of dominance index, evenness index, and Margalef's species richness index varies significantly ($p<0.10$) between managed and control blocks. Similarly, post hoc analysis showed that the mean value of Shannon-Weiner diversity, the concentration of dominance, and evenness indices vary significantly ($p<0.05$) between managed block I and control block as well as managed block II with control block (Table 1). The difference in mean species richness index from the control block was found to be significantly different from that of managed block I (p-value < 0.05) but only marginally different from that of the managed block II ($p < 0.10$).

Table 1: Mean and standard errors of species diversity indices

Block	(H')	(C)	(E)	(S)
Managed block I	0.66±0.06	0.66±0.04	0.49±0.07	0.77±0.13
Managed block II	0.88±0.19	0.58±0.09	0.47±0.09	1.18±0.14
Control block	1.24±0.05	0.39±0.02	0.71±0.03	1.57±0.08

Note: *H′ is the Shannon Wiener's Index; C: Simpson's Dominance Index/Concentration of Dominance; E: Evenness Index and S: Species Richness Index*

The Jaccard's Similarity Index showed a high similarity in the species between managed block II and control block (unmanaged) block of the study area (Table 2). There was a high dissimilarity between managed block I with the control block that may be due to the post-harvesting of unwanted species in the course of weeding and cleaning.

Table 2: Jaccard's Similarity Index

Area of interest	Jaccard's Index (%)
Managed block I with managed block II	43.75
Managed block I with control block	37.50
Managed block II with control block	50.00

Regeneration status

Forest Condition

Overall, the seedling density (17240 Ind/ha) and sapling density (2280 Ind/ha) were found to be highest in the managed block II, as shown in Figure 3. The control block showed the least seedling density (6133.33 Ind/ha) among the three blocks, as shown in Figure 3. However, the sapling density (2280 Ind/ha) in the control block was found to be higher than the block I. The tree density (263 Ind/ha) remained higher in the control block where regeneration felling was not conducted.
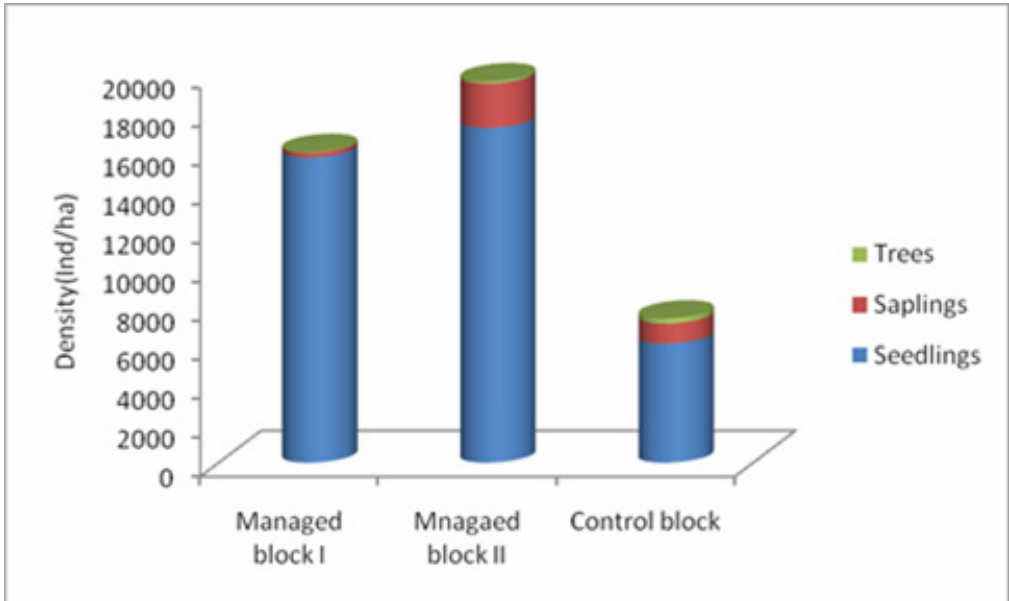

Figure 3: Seedling, sapling and tree density in the forest

Regeneration of S. robusta in contrast to other species

The seedling density of *S. robusta* was found to be higher in the managed area (Block II with 13680 Ind/ha and Block I with 12840 Ind/ha) and lower (4100 Ind/ha) in the control block (Figure 4). Similarly, the sapling density was also found to be higher in the managed area (Block II with 800 Ind/ha and Block I with 200 Ind/ha) and lower (127 Ind/ha) in the control block. In contrast to the other species, the seedling density of *S. robusta* was found to be relatively higher in the managed Block II followed by Block I and the lowest in the control block.
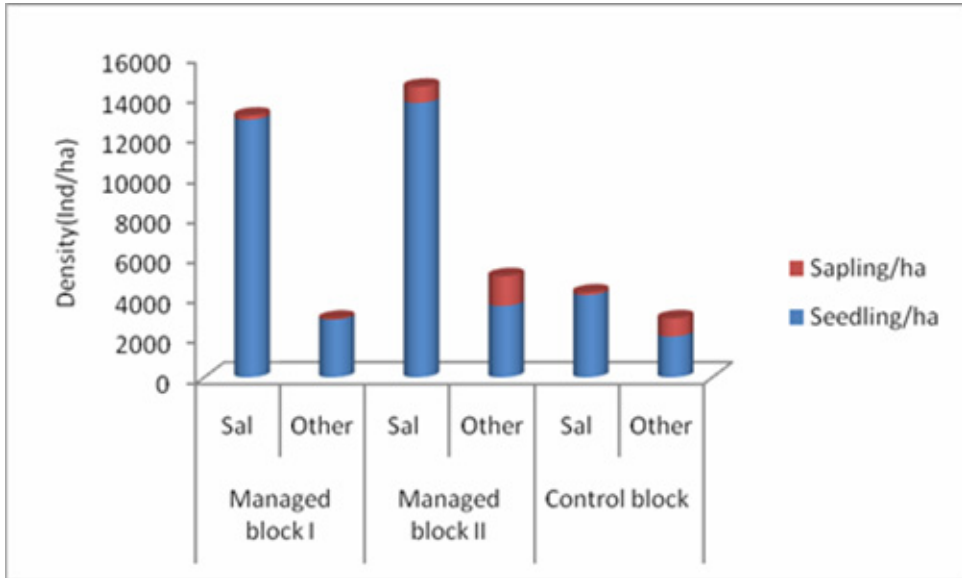
Figure 4: Regeneration comparison of *S. robusta* with other species

Relationship of Regeneration/Diversity of the Forest with Crown Cover

The total seedling and specific Sal seedling density were found to be strongly negatively correlated with the canopy cover while total sapling, as well as sapling density of Sal, remain statistically not significant (Table 3), representing the role and significance of canopy opening in developing environments for seedlings rather than that of saplings. Similarly, the value of Shannon Weiner's index and Evenness index showed a significant positive correlation with canopy cover while the concentration of Dominance index value was found significant negatively correlated with canopy cover. On the other hand, Species richness showed a positive correlation with canopy cover, though found statistically insignificant (Table 4).

Table 3: Correlation between canopy cover and regeneration of the forest

	Seedling density	Sapling density	Sal seedling	Sal sapling
Canopy cover	- 0.78** 0.000	-0.18 0.252	- 0.762** 0.000	- 0.211 0.19

Table 4: Correlation between canopy cover and species diversity of the forest

	H'	C	E	S
Canopy cover	0.50** 0.001	- 0.68** 0.000	0.813** 0.000	0.20 0.21

*Note: H' is the Shannon Wiener's Index; C: Simpson's Dominance Index/Concentration of Dominance; E: Evenness Index and S: Species Richness Index; ** represent significant at 0.01 level of significance (2-tailed)*

Climate, Vegetation and Productivity (CVP) index

The CVP index and the potential productivity of the study area were found to be 1112.3 and 8.60 cubic meters per hectare per year, respectively. For this analysis, climatic data were derived from 43 years of data from 1971-2014 published by DHM Nepal (DHM 2017). The average precipitation used was 1719 mm, while the mean maximum temperature for hot weather was taken as 23.9⁰C, 8 months as a growing period out of 12, and 46% as evapotranspiration rate as determined by the location of the site based on the method prescribed by Paterson (1956).

Existing and Projected Flow of Forest products from the Forest

Based on the Community Forest Management Operation Plan, the total growing stock of the community forest and periodic block (C1SC7) was 195.48 m^3/ha and 202 m^3/ha respectively and also expected to generate timber of 17036.71 cft and firewood of 9500 cft annually from management operations. The major sources for the flow of timber and firewood from the forest were regeneration felling operations followed by post-harvest, cleaning, and sapling thinning and so on in an appropriate block in proper intensity as required and also from the development of firelines within the periodic block (C1SC7) and collection of dead, dying and diseased trees throughout the forest area. The production of timber (round) and firewood were 12,859.3 cft and 18,000 cft, respectively, in the first year (FY 2017/18) and 18,718.8 cft and 25,250 cft, respectively, in the second year (FY 2018/19) (Figure 7). Among them, most of the timber and firewood were recorded to be generated from regeneration felling (41%) and firelines development operation (41%) followed by the collection of dead, dying, and diseased trees throughout the CF (18%), revealing the higher production of forest products in implementing the SciFM plans in contrast to the passive management which focused only on selective felling of dead, dying and diseased trees.

The average number of trees in the managed blocks I and II were found to be 98/ha and 86/ha respectively. The number of felled trees per ha in the managed blocks I and II were 81 and 68 respectively generating timber of 6532 cft and 6292 cft respectively, and firewood of 10500 cft and 10000 cft respectively. The number of mother trees per hectare retained in the managed blocks I and II are respectively 17 and 18 for securing the quality seeds for promoting the regeneration. Similarly, the average annual projected production of timber and firewood in managing the remaining 8 annual sub-blocks through only regeneration felling would be 2232 cft/ha and 3500 cft/ha, respectively. Besides, an average annual projected timber and firewood production in the rest of 8 years would be 5464.12 cft/ha and 7502.71 cft/ha respectively.
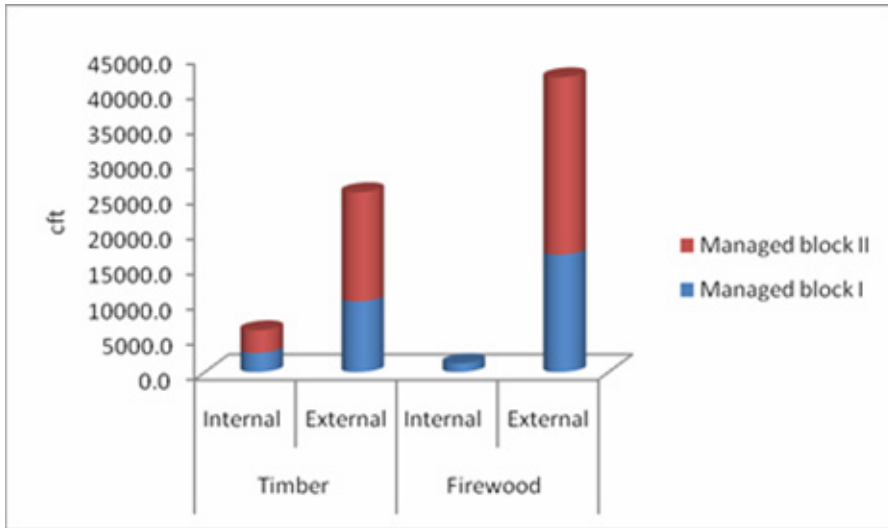
**Figure 7: Consumption of forest products obtained from forest**

Two consumption patterns of timber and fuelwood generated from forest were observed, i) internal within user groups and ii) external (outsourcing). In this regard, the internal consumption of the forest products (either timber or firewood) was found to be quite lower and most of them were found sold through biddings in the past two years (Figure 7).

Existing and Projected Flow of Income and Expenditure from Forest

The flow of income and expenditure incurred in managing community forest (regeneration felling, firelines creation, collection of dead, dying, diseased trees and post-harvest operation) in two fiscal years are shown in figure 8. As for determining expenditure in managing the Periodic Block I of the forest, initial cost before initiating the specific SciFM plans included cost for a boundary survey, stem mapping, fire line construction, fencing around the periodic block, and cost regarding the preparation of the plan, which was 10,973 US$[*]. The costs mainly included in SciFM are forest management cost (weeding, cleaning, thinning, and plantation), maintenance cost, protection cost (patrolling/forest watcher), timber, and firewood collection/harvesting, fireline development, and plowing/ regeneration promotion activities in regeneration felled areas. The audit report of CFUG showed that the higher expense was on forest management, followed by harvesting, and administrative expenses. The total expense was 52,547 US$ in the last two years. At the market price, the total income generated in two fiscal years from forest products was 239,924 US$. Thus, the net total benefit generated in the last two years was approximately 187,000 US$, while the net projected benefit generation from the forest in managing the rest of 8 years was 633,000 US$, after deducting all

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[*] *1dollar (US $) = 100 Nepalese Rupees*

the relevant expenditures related to management that may occur in future. The higher the net benefit generation from management (the gap between management cost and potential incomes), the more would be opportunity and alternatives for community user groups in community development and income generation activities.
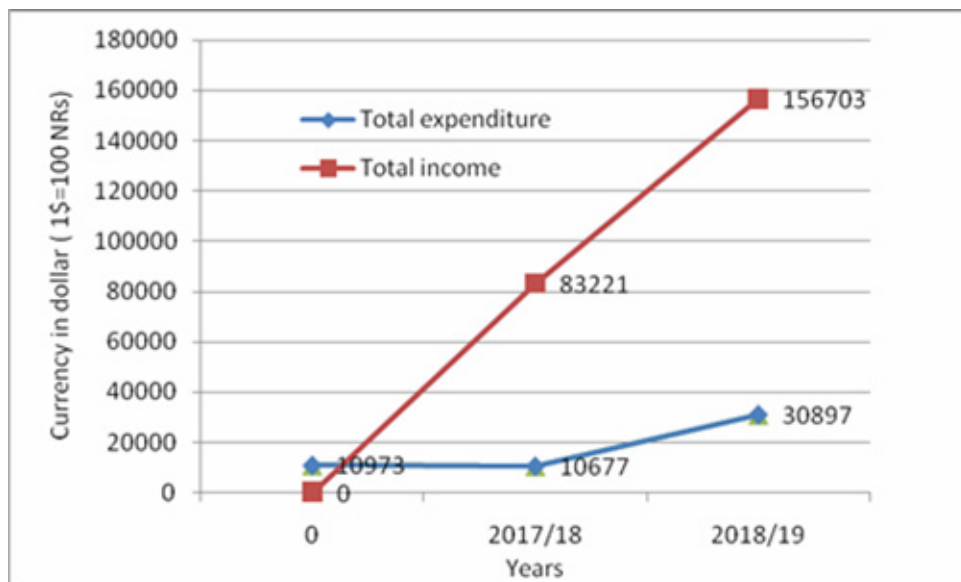
Figure 8: Flow of cost and income in managing Community forest

Discussion

The study found that implementing SciFM in community forest ensures the promising forest health in terms of sound regeneration of intended species (*S. robusta*) and the productivity of forest through the flow of forest products (timber and firewood). This could further lead to the profitability for the community users group in regulating the forest yields under a silvicultural system.

In all the blocks, Sal (*S. robusta*) was found to be the dominant species followed by Asna (*T. tomentosa*), which is similar to the findings of the Terai forest inventory of 2010-2012 (DFRS 2015). Odum (1971) emphasized the contagious distribution patterns as the most common patterns in nature, which indicates that most seedlings were adapted to grow closer to the mother plants. The study encountered about 80%, 38%, and 78% of the total species as contagiously distributed in the managed block I, II, and the control block, respectively. The lower proportion of contagiously distributed species in the managed block II might be the result of species having either lower abundance or lower frequency, as four species were recorded for only once in all the five plots sampled in managed block II.

The SciFM has a negative effect on the plant diversity, shown by the lower value of Shannon-Weiner's index in the managed blocks in contrast to the control block. Similarly, results were further drawn by a significant positive correlation between the diversity index and canopy cover. Sapkota et al. (2010) found a decline in the tree diversity while increment in the dominance of *S. robusta* linearly along the disturbance gradient in the Nepalese Sal forest, similar to our study (Table 1). Mohammadi et al. (2008) and Awasthi et al. (2015) also found a decrease in the species diversity where Shelterwood Silvicultural System was practiced in the natural forest stands, similar to the results obtained. The species composition and diversity are related to the intensity of logging and type of management practices (de Avila et al. 2015), which means the higher the harvesting intensity the lower the species diversity in SciFM practices (Shima et al. 2018; Awasthi et al. 2020). Halpern and Spies (1995) also found other management activities (fertilization, herbicide application, grazing) could affect the species composition of vegetation in addition to the initial effect of logging and site preparation. However, a study by Carreño-Rocabado et al. (2012) stated that disturbance intensity has almost no role in altering species richness or even the predicted species richness, which might be the effect of lower logging intensity.

The seedlings density of *S. robusta* was found higher in both the managed blocks in contrast to the control block. As per the definition of the status of regeneration (good, satisfactory, poor), the seedlings density was good in the managed blocks while just satisfactory in the control block (MFSC 2004), but the saplings density seemed poor in managed block I and control block while satisfactory in managed block II. The lower density of saplings in the managed block I might be the poor initial condition or advance growth in the block before regeneration felling with respect to the managed block II. The seedling density of *S. robusta* was higher after regeneration felling, while a similar result was obtained by Rautiainen and Suoheimo (1997). Similarly, higher seedling and sapling density of *S. robusta* was observed by Khanal and Adhikari (2018) in the scientifically managed forest in the Rupandehi district of Nepal, where Sal regeneration obtained higher light intensity under canopy opening for their growth. This result has been further confirmed by the significant negative correlation between canopy cover with seedlings density of Sal; similarly depicted by the lower density of seedlings in case of control or natural stands where the canopy was dense with lower overhead light for the under storey vegetation. This showed good regeneration in the managed area (block I and II) either in terms of seedlings or saplings density in comparison to the unmanaged area (control block) that predicts good future generation and productivity of the forest.

The estimated value of current annual increment (CAI) of forest in Nepal is 0.6 to 1.2 cubic meter per hectare, which is far below the potential productivity (8.60 cubic meters per hectare) of the site as determined by Paterson (1956) method, showing the potential to be increased 5-6 times if forests are managed scientifically (FAO 2009). The calculated potential productivity (CVP index, 1112.3) of the site lies within the CVP index class developed for moist and dry Sal (500-2000) by Champion et al

(1965). A study report of NFA (2012) projected the timber and fuelwood demand for the Terai region would be 1.46 million cubic meters and 5.3 million tons respectively in 2020, and supply is far less than demand projected as indicated by ever-increasing timber price. Moreover, about 86% of households within the Kailali district consumed firewood as fuel followed by Liquid Petroleum Gas (7%), showing high dependency upon the forest for fuel also (DDC 2015). Though Nepal has an area of 44.74 % covered by forests and a large number of trees and timber (nearly 37.6 million cubic feet) die and decay in the forest, over 80% of timber (nearly 29.3 million cubic feet) was found imported from the foreign countries like Malaysia, Indonesia, Burma and so on in 2015, according to Federation of Forest-Based Industry and Trade, Nepal (*The Himalayan Times* 2016; Baral and Vacik 2018).

Effectiveness of any forest management practices relies on complexities or adoption and the cost or profit made (Poudyal et al. 2019). However, this study acknowledged some of the limitations as (1) cost regarding managing the matured natural forest might be underestimating and less in concluding the profitability studies as associated indirect cost and cost of raising the matured forest is missing (2) associated indirect benefits (monetary value) in managing the forest (natural regeneration/health of forest) were not computed (3) potential productivities based on climatic data were not compared with periodic measurement of similar types of managed forest. Meanwhile, passive forest management based on selective felling of the dead, dying, and diseased trees may promote the timber smugglings and degradation of the forest as demands of local people are not being entertained by the government (Subedi 2011). Also, the economic analysis such as the Benefit/Cost ratio and the Internal Rate of Returns almost ensured the positive impacts from the SciFM. The benefit-cost ratio of three of the collaborative forests (Tilaurakot, Gautam Buddha, and Banganga) was 4:1, 3:1, and 3.5:1 (Subedi 2011). This indicates the profitability and need for managing the natural forest scientifically rather than letting them decay and degrade as in the contemporary protection management regime.

Conclusion and Recommendations

This study was conducted to analyze the effects of SciFM on the regeneration of Sal (*S. robusta*), plant species diversity, and income through the flow of forest products in the community forest. The seedling density of *S. robusta* in the managed area was found to be higher than that in the unmanaged area of forest, which was also observed by the higher correlation of seedling density with canopy opening at their earlier stage of management practices. Plant diversity in unmanaged areas was found to be higher than in the managed area of forest affecting the species richness and evenness. The density of seedlings of *S. robusta* was low in the unmanaged area of forest, though the area has been fenced, which shows the need of opening the canopy for the promotion of regeneration in the study area. Paterson's CVP Index of the site was higher and its potential productivity was maximum. The productivity of the forest was found to be highest in both volumes of forest products and income in

the last two years. Thus, SciFM promotes regeneration to reduce forest degradation, fulfill timber and fuelwood demand, and generate potential income for the community. SciFM, hence could be useful for the overall betterment of the remaining forest and associated communities in line with the slogan of "Forestry for Prosperity". Future research should explore the long term impacts of SciFM on plant species diversity. The market demand should be responded with appropriate management of forest and ensured a steady supply of forest products. In addition, there is also the need for developing large data sets on the permanent plots for understanding the long-term dynamics of regeneration, growth, wood production, and hence profitability from managing the community forest based on the silvicultural grounds.

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