

## Vegetation Structure and Species Diversity in Community Managed Sal (*Shorea robusta*) Forest of Tanahun District, Nepal

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### ABSTRACT

Vegetation structure and species diversity were studied in four community managed *Shorea robusta* forests in mid-hill zone of Tanahun district, Nepal. These forests have been managed for 6 to 21 years by communities. A stratified random sampling method, using square quadrats was used for vegetation and soil sampling. Altogether 100 quadrats were sampled to determine the Importance Value Index (IVI) of tree species, species diversity and soil attributes. Soil was collected from each quadrat and their physicochemical characteristics (soil pH, organic carbon, total nitrogen, available phosphorus and potassium) were analyzed. Altogether 29 and 27 tree species were recorded in forests managed by communities more than 10 years (MCF) and forests managed by communities equal or less than 10 years (LCF) forest, respectively. Tree density was higher in MCF forest and shrub density was higher in LCF forest. Regeneration was assessed by density-diameter curve. The density diameter curve of the tree population of Sal on MCF and LCF forests indicates reversed J-shaped structure and show satisfactory regeneration. High priority had been given for the conservation of Sal in both forests. Regeneration of co-dominant species *Schima wallichii* was sustainable in both forests. The study found that most community forests are moving toward promoting limited timber yielding species that have high economic value. The species diversity index of species was higher in MCF forest than in LCF forest. This study will be helpful in the formation of effectual forest management and conservation strategies.

**Key words:** Community Management, Density, Diameter, Diversity index, Regeneration

### INTRODUCTION

A plant community is a composition of plant species growing together in a specific location with a definite association with each other (Singh et al. 2016). Community structure of forest is directly regulated by species diversity which is the biological basis to maintain ecosystem functions (Tilman and Dowing 1994). The species composition of forests depends on the regeneration of species present in the forest in space and time. The structure of tree diversity in hill forests differs from place to place due to variation of altitude, orientation of slope, nature of soil and type and intensity of disturbances (Vetaas 2000). Study of forest community structure is very essential in order to manage the forest resources in a sustainable basis, which includes essential features such as structural type, size, shape and both vertical and horizontal spatial distribution (Spies et al. 1998). Similarly, analyses of diversity of forest component, natural regeneration, etc. are important variables to assess the forest status in terms of growing stock, dynamics, forest and sustainable management. Such

information would be helpful in developing a management strategy of the forest. Forest structure is both a product of forest dynamics and a template for biodiversity and ecosystem function. Knowledge of species composition and diversity of tree species is important to understand the structure of a forest community, status of tree population, regeneration and diversity (Singh et al. 2016, Manna and Mishra 2017). Quantitative inventories also help in the identification of economically useful species as well as the species of special concern, i.e. rare, endangered, endemic, threatened or vulnerable species (Keel et al. 1993), and thus have great implications in the conservation and management of forests (Manna and Mishra 2017). The structure and vegetation diversity at any site are influenced by species distribution, abundance patterns, topography, soil, climate and geographical location of a region (Khaine et al. 2018, Bhatta and Devkota 2020).

Community forestry programme has an important role in the conservation of biodiversity, ecosystem services, livelihood and capacity development of local peoples through sustainable use of forest

resources (Shrestha et al. 2010, Luintel et al. 2018). But the recent concern is whether the management practices are ecologically sustainable or not. Earlier studies have shown that due to management practices, various changes are occurring in the Nepalese community forests (CFs), including Sal (*Shorea robusta* Gaertn.) dominated CFs, related to structure, composition and regeneration (Shrestha et al. 2010, Oli and Subedi 2015, Sapkota et al. 2018). Information regarding the structure, composition and regeneration on Sal forests from mid hill Nepal is still inadequate. Therefore, the present study was sought to inspect the status of forests, analyze species diversity and to assess the regeneration pattern of community managed Sal dominated forest at two developmental stages (age of forest after community management) of Tanahun district; to know the impact of management time on regeneration. For this, we selected four Sal-dominated community managed forests (CFs).

## MATERIALS AND METHODS

### Study Area

The study area is located in Byas Municipality Tanahun District of Central Nepal between 27.91 to 27.55 N latitude and 84.25 to 85.15 E longitude with elevation 280 - 1220 m. from above sea level (Fig. 1). The climatic zone varies from tropical to subtropical. The climate of the study area is subtropical monsoonal with four distinct seasons: winter (December to February), spring (March to May), summer (June to August) and autumn (September to November). The study was carried out in June and forests dominated by Sal were included in the study. Based upon the information accumulated during the preliminary survey, we selected four Sal-dominated CFs (Table 1) and categorized them into two developmental stages (more than 10 years (MCF) and less than 10 years (LCF) of forest management by the local community) (hereafter referred to as forest categories).

In all the study forests, *Shorea robusta* was the dominant vegetation with the major associated species such as *Schima wallichii*, *Semecarpus anacardium* and *Castanopsis indica*. Fodder collection of woody species and cattle grazing were mainly prohibited in all the CFs since it was handed

to them. Firewood collection was allowed once in a year in all the studied CFs. Cleaning (removal of unwanted shrubs and weeds and singling of desired species); thinning/pruning were the chief silvicultural operations done after the forest has been handed over to the community. The intensity of thinning exclusively depends on traditional knowledge. Dead, dying, crooked, malformed and weak trees are preferentially removed in this system. Fire is strictly prohibited in all the CFs.

### Field survey and data collection

For vegetation sampling stratified random sampling method was followed. The forest blocks designated by the Community Forest Users' Group (CFUGs) were considered as strata. Square quadrat of 10 m×10m was sampled for trees, 5m×5m for shrub layer (including saplings of tree) and 1m×1m for seedlings. Of hundred quadrats, 50 were laid in LCF and 50 in MCF forests. Each quadrat of 10 m×10 m was divided into four subplots from the center of the quadrat and one subplot was randomly taken for sampling of shrub. One of the four corners of the plot was selected randomly where 1m×1m quadrat was defined: all seedling of *Shorea robusta* within this quadrat was sampled. In each CFs about 0.50 ha area of forest was sampled. In each 10m×10m quadrat, the number of individual tree [diameter at breast height, dbh  $\geq$  5 cm] of each species was counted and dbh of each tree was measured. For shrubs/sampling (dbh < 5.0 cm, height > 137cm) the number of individuals of each species was counted. For seedling of *Shorea robusta* which height <137 cm the number of individuals was counted (DFRS 2014a, b).

About 200 g soil sample was collected from a depth of 15 cm from the centre of each plot during field visit. The soil samples were air-dried in shade for a week and packed in airtight plastic bags for laboratory analysis. The soil parameters such as soil organic carbon, pH, total nitrogen, available phosphorus and available potassium were determined at laboratory of Soil Test Center, Pokhara, by applying Walkley–Black rapid titration method, potentiometric method, Kjeldahl method, Olsen's method and flame photometer method, respectively (PCARR 1980). The plant specimens were identified with the help of literatures (Malla et al. 1986,

Table 1. Community forests taken for study

Sl. No.	Name of CF	Name of VDC	Area (ha)	Year of Handover	Management duration (Years)	No. of plots	Category of CF based on management duration
1.	Foksing CF	Byas-6	252.77	2005	10	25	CF managed for equal or less than 10 years (LCF)
2.	Manebanjyang CF	Byas-6	146	2009	6	25	CF managed for equal or less than 10 years (LCF)
3.	Janakalyan CF	Kyamin-7	160	2001	14	25	CF managed for more than 10 years (MCF)
4.	Hariyali CF	Kyamin-7	306.2	1994	21	25	CF managed for more than 10 years (MCF)

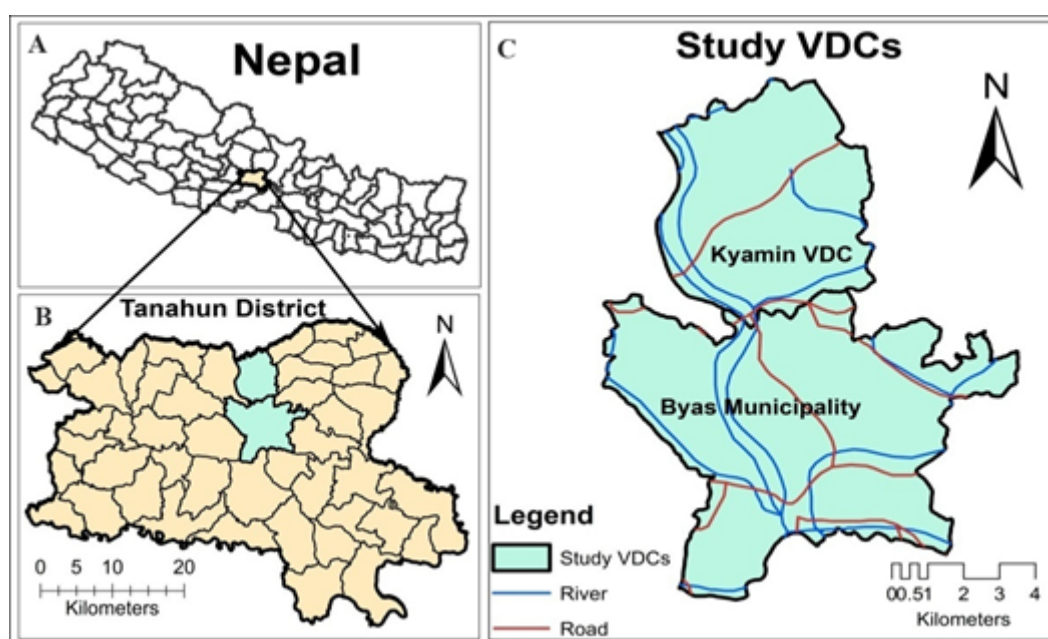


Figure 1. Map showing A) Nepal, B) Tanahun district and C) study VDCs (*Source: Department of Survey, GoN*)

Siwakoti and Varma 1999) and by tallying with the specimens at Tribhuvan University Central Herbarium (TUCH). The nomenclature of specimens follows Press et al. (2000).

Regeneration status of forests was assessed at three life stages, viz. seedling, sapling and tree, considering seedling as <137 cm height, sapling as < 5 cm DBH and >137cm height and tree as  $\geq 5$  cm DBH (DFRS 2014a, b). The number of saplings and trees was recorded in 10 m  $\times$  10 m quadrats, while seedlings number was counted in two diagonally opposite 2  $\times$  2 m quadrats nested within a 10 m  $\times$  10 m quadrat. Canopy cover for each plot was estimated

by visual estimation method from center of the plot. Ground litter cover, grazing and silvicultural activities were also recorded visually during filed survey.

#### Data analysis

The data were analysed to calculate the frequency, density, basal area, relative values of frequency, density, basal area and importance value index (IVI) following the method described in Zobel et al. (1987). To assess the regeneration status of the forest, the density of seedling, sapling and tree were determined separately following the method described in Zobel

et al. (1987). A total number of plants of all species recorded in all 10 m × 10 m quadrats were divided into different size classes based on DBH of 5-cm intervals. Size class diagram of the study area, dominant and co-dominant tree species were prepared to analyse the structural composition. The species richness was calculated as the number of species present per sample plots (Timilsina et al. 2007). Diversity index ( $H'$ ) was also calculated following the Shannon and Weiner formula:  $H' = -\sum p_i \log p_i$ ; where,  $p_i$  = the proportion of importance value of the  $i^{\text{th}}$  species,  $p_i = n_i/N$ ,  $n_i$  is the importance value of  $i^{\text{th}}$  species and  $N$  is the importance value of all the species (Zobel et al. 1987).

Descriptive statistics were applied to generate means and standard error. The mean values of the tree and stand variables, soil properties and regeneration status of plant species were compared between two forest categories by  $t$  test. Prior to  $t$ -test, data were tested for normality (Shapiro–Wilk test,  $p > 0.05$ ). Normal data were compared by  $t$ -test. Correlation analysis was performed to access the relationship of regeneration with different plot variables. All these analyses were done using Microsoft Excel 2007 (Microsoft Corporation 2007) and the Statistical Package for Social Science (SPSS version 20).

## RESULTS AND DISCUSSION

### Forest structure and phytosociological characteristics

Altogether, 35 tree species belonging to 34 genera and 23 families and 45 shrub species belonging to 44 genera and 23 families were recorded (Tables 2 and 3). There was variation in total number of tree and shrub species between MCF (more than 10 years management) and LCF (less than 10 years management) forest category. This variation may be due to the difference in management activities and disturbance between both categories of forests (Kushwaha and Nandy 2012, Bhatta and Devkota 2020). The forests included in MCF management category seen to be properly managed with a lower disturbance which may have ensured higher tree species. But, forests included in LCF management category were subjected to higher and recurrent disturbance which may have resulted in lower tree

species and higher shrub species.

The number of tree and shrub species in present study was found almost similar to plantation hilly Sal forests of Tanahun (Oli and Subedi 2015), Rupandehi (Acharya and Shrestha 2011), Dadeldhura (Bhatta and Devkota 2020) and Shivalik Sal forests of Nainital (Adhikari et al. 2017). However, a number of tree and shrub species were found higher than the tropical Sal forests of Palpa (Basyal et al. 2011) and hilly Sal forest of Kaski (Paudyal 2013). But, a number of tree and shrub species were lower than the Sal-dominated forest of Banke (Napit 2015) and West Bengal (Manna and Mishra 2017). The variation in habitat, climate, soil, geographical location, disturbance and management practice may be the cause of variation in a number of tree and shrub species between the present study and above-mentioned studies (Kushwaha and Nandy 2012, Khaine et al. 2018).

Our results showed that Sal is the highly dominant species of the study area, while remaining species were infrequent, rare and sparsely distributed. Species preference, management activities, overutilization and removal of other species from a mixed forest stand were the common disturbance activities of the CFs (Shrestha et al. 2010). We also observed the similar types of disturbances during field sampling where Sal has given proper attention to protection. Similar results have been reported by previous researchers also (Sarkar and Devi 2014, Das et al. 2017). The dominance of Sal may be due to its protection (Mandal and Joshi 2014), low soil pH and low nitrogen and high potassium content (Bhatnagar 1965).

Total density, tree density and shrub density of the study area were 10,200 plants ha<sup>-1</sup>, 1272 trees ha<sup>-1</sup> and 8928 shrub ha<sup>-1</sup>, respectively (Table 4). Total density and tree density in MCF forest category were greater than LCF forest category, while shrub density was higher in LCF forest categories. Higher tree density in MCF forest category than LCF forest category is due to low disturbance (Naidu and Kumar 2016), low canopy cover (Sapkota et al. 2010) and low soil pH (Bhatnagar 1965, Bhatta and Devkota 2020). The tree density was higher than the tree density obtained from the Sal forests from other region of Nepal (Timilsina et al. 2007, Acharya and Shrestha 2011, Basyal et al. 2011, Napit 2015, Oli

Table 2. Density (D, individuals/ha), Basal Area (BA, %) Importance Value Index (IVI) and families of tree species of LCF and MCF forest.

SN	Name of species	Sites						Family
		MCF			LCF			
		D	BA	IVI	D	BA	IVI	
1	<i>Adina cordifolia</i> (Wild.exRoxb.) Benth. and Hook.f.exBrandis	-	-	-	8	0.0026	2.31	Rubiaceae
2	<i>Aegle marmelos</i> (L.) Corr.	-	-	-	8	0.0034	2.39	Rutaceae
3	<i>Albizia chinensis</i> (Osbeck) Merr.	8	0.0053	2.34	2	0.0006	0.69	Fabaceae
4	<i>Alstonia scholaris</i> (L.) R.Br	10	0.0052	2.99	6	0.0059	2.48	Apocynaceae
5	<i>Anthocephalous chinensis</i> (Lam.)A.Rich.	-	-	-	2	0.0002	0.64	Rubiaceae
6	<i>Aporosa dioca</i> (Roxb.) Muell-Arg	-	-	-	10	0.0045	2.49	Phyllanthaceae
7	<i>Azadiiracta indica</i> A.Juss	2	0.0023	0.97	-	-	-	Meliaceae
8	<i>Bombax ceiba</i> L.	12	0.0157	4.03	8	0.0018	2.03	Malvaceae
9	<i>Bridelia retusa</i> (L.) Spreng	2	0.0002	0.68	10	0.0005	2.85	Phyllanthaceae
10	<i>Callicarpa arborea</i> Roxb.				2	0.0738	0.68	Lamiaceae
11	<i>Castonopsis indica</i> (Roxb.) Miq	10	0.0024	4.46	132	0.0095	26.64	Fagaceae
12	<i>Cedrella toona</i> Roxb.				16	0.0008	4.44	Meliaceae
13	<i>Cleistocalyx operculata</i> (Roxb.) Merry. and Perry.	16	0.0042	4.32	28	0.002	7.13	Myrtaceae
14	<i>Dillenia pentagyna</i> Roxb	8	0.0027	2.49	6	0.0033	2.12	Dilleniaceae
15	<i>Engelhardia spicata</i> (Lesch.) Blume	30	0.0046	9	24	0.0011	6.01	Juglandaceae
16	<i>Golchidion</i> sp.				8	0.0042	2.62	
17	<i>Holarrhena pubescens</i> (Buch-Ham) Wall.ex G.Don	16	0.0028	4.13	10	0.0045	3.56	Apocynaceae
18	<i>Lagerstromia parviflora</i> Roxb.	16	0.0018	5.01	32	0.0027	7.23	Lythraceae
19	<i>Lanneacoro mandelica</i> (Houtt) Merr.	4	0.0176	3.67	-	-	-	Anacardiaceae
20	<i>Magnifera indica</i> L.	12	0.0091	4.17	4	0.0014	1.53	Anacardiaceae
21	<i>Mallothus phillippensis</i> (Lam.) Mull.	6	0.0007	1.56	10	0.0024	3.28	Euphorbiaceae
22	<i>Millettia extensa</i> (Benth.) Benth. ex Baker	10	0.0015	2.49	18	0.0002	4.96	Fabaceae
23	<i>Phyllanthus emblica</i> L.	10	0.0032	2.72	2	0.0053	4.65	Phyllanthaceae
24	<i>Pterospermum lanceofolium</i> Roxb.	32	0.0161	8.14	-	-	-	Sterculiaceae
25	<i>Rhus javanica</i> L.	-	-	-	2	0.0002	0.64	Anacardiaceae
26	<i>Sapium insigne</i> (Royle) Benth.	2	0.0004	0.71	-	-	-	Euphorbiaceae
27	<i>Schima wallichii</i> (D.C) Korth	206	0.109	48.54	160	0.1197	42.81	Theaceae
28	<i>Semecarpus anacardium</i> L.	56	0.0163	10.51	6	0.0006	1.14	Anacardiaceae
29	<i>Shorea robusta</i> Gaertn.	708	0.4501	139.51	638	0.6862	144.62	Dipterocarpaceae
30	<i>Spondia spinnata</i> (L.f.) Kurz	4	0.0017	1.55	8	0.0051	2.55	Anacardiaceae
31	<i>Syzygium cumini</i> (L.) Skeels	14	0.0019	2.85	-	-		Myrtaceae
32	<i>Terminalia alata</i> Heyne ex Roth	58	0.0477	16.76	26	0.0237	7.77	Combretaceae
33	<i>Terminalia bellerica</i> (Gaertn.) Roxb.	26	0.0132	7.82	12	0.0054	4.31	Combretaceae
34	<i>Trewia nudiflora</i> L.	20	0.0058	5.34	-	-	-	Euphorbiaceae
35	<i>Walsura tabulata</i> Hiern.	8	0.0075	3.63	12	0.0114	3.99	Meliaceae
<b>Total</b>		<b>1314</b>	<b>0.7508</b>	<b>300.48</b>	<b>1230</b>	<b>0.9874</b>	<b>299.96</b>	

and Subedi 2015) and India (Tripathi and Shankar 2014, Manna and Mishra 2017). However, shrub density was within the range of Sal dominated forest of Banke (Napit 2015), lower than hill Sal forest of Rupandehi (Acharya and Shrestha 2011) and higher than tropical Sal forests of Bardia and Kanchanpur (Timilsina et al. 2007). Species composition, degree

of disturbance, anthropogenic activities and soil properties may be the cause for the variation in density between the forests (Sapkota et al. 2010).

Total basal area in the MCF forest and LCF forest was 0.75 and 0.99%, respectively. Both values were higher than the value (0.11%) reported by Webb and Shah (2003) in natural forest of Terai, the value

Table 3. Density (D, individuals/ha), frequency, and families of shrub and saplings of species of LCF and MCF forest

SN	Name of species	MCF		LCF		Families
		D	F	D	F	
1	<i>Adina cordifolia</i> (Wild. ex Roxb.) Benth and Hook.f.exBrandis#	16	4	-	-	Rubiaceae
2	<i>Albizia chinensis</i> (Osbeck) Merr #	8	2	16	4	Mimosaceae
3	<i>Alstonia scholaris</i> (L.) R. Br #	64	10	16	4	Apocynaceae
4	<i>Antidesma diandrum</i> Roth.	48	8	-	-	Phyllanthaceae
5	<i>Asparagus racemosus</i> Wild.	8	2	56	4	Asparagaceae
6	<i>Bombax ceiba</i> L.#	16	4	64	10	Malvaceae
7	<i>Bridelia retusa</i> (L.) Spreng #	8	2	112	24	Phyllanthaceae
8	<i>Cedrella toona</i> Roxb. #	32	6	64	22	Meliaceae
9	<i>Caesalpinia decapitala</i> (Roth.) Alston	40	10	16	10	Fabaceae
10	<i>Callicarpa arborea</i> Roxb. #	80	16	104	18	Lamiaceae
11	<i>Callotropis gigantea</i> (L) Dryand	18	6	-	-	Apocynaceae
12	<i>Castonopsis indica</i> (Roxb.) Miq #	76	16	788	76	Fagaceae
14	<i>Citrus medica</i> L.	28	2	-	-	Rutaceae
15	<i>Cleistocalyx operculata</i> (Roxb.) Merry. and Perry. #	40	10	248	38	Myrtaceae
16	<i>Clerodendrum viscosum</i> Vent.	328	60	96	20	Lamiaceae,
17	<i>Cornus oblonga</i> (Wall.) Sojak	72	10	-	-	Cornaceae
18	<i>Dillenia pentagyna</i> Roxb #	248	40	148	12	Dilleniaceae
19	<i>Engelhardia spicata</i> (Lesch.) Blume #	56	14	232	44	Juglandaceae
20	<i>Elaeagnus parviflora</i> Wall.ex Royle	-	-	32	8	Elaeagnaceae
21	<i>Ficus semicordata</i> Buch.-Ham.ex Smith	64	12	-	-	Moraceae
22	<i>Golchidion</i> sp. #	-	-	72	4	Euphorbiaceae
23	<i>Holarrhena pubescens</i> (Buch-Ham) Walll.exG.Don #	40	8	88	18	Apocynaceae
24	<i>Hydrangea anomala</i> D.Don	-	-	80	16	<i>Hydrangeaceae</i>
25	<i>Lagerstromia parviflora</i> Roxb. #	88	16	336	60	Lythraceae
26	<i>Litsea monopetala</i> (Roxb.) Pers.	72	12	140	22	Lauraceae
27	<i>Lyonia ovalifolia</i> (Wall.)	152	28	224	8	Ericaceae
28	<i>Maesa chisa</i> Buch-Ham .ex D.Don	48	10	40	6	Primulaceae
29	<i>Mallotus philippensis</i> (Lam.) Mull #	96	18	208	36	Euphorbiaceae
30	<i>Milletta extensa</i> (Benth.) Benth.ex Baker #	104	22	312	52	Papilionaceae
31	<i>Mussa endatretuleri</i> Stapf	192	38	188	42	Rubiaceae
32	<i>Phyllanthus emblica</i> L.#	176	32	104	18	Phyllanthaceae
33	<i>Pterospermum lanceofolium</i> Roxb. #	72	14	-	-	Malvaceae
34	<i>Rhus javanica</i> L. #	16	4	48	8	Anacardiaceae
35	<i>Sapium insigne</i> (Royle) Benth. #	24	6	200	16	Euphorbiaceae
36	<i>Schima wallichii</i> (D.C) Korth #	992	74	800	76	Theaceae
37	<i>Semecarpus anacardium</i> L. #	272	58	64	12	Anacardiaceae
38	<i>Shorea robusta</i> Gaertn. #	4728	100	3920	100	Dipterocarpaceae
39	<i>Spondias pinnata</i> (L.f) Kurz #	-	-	16	4	Anacardiaceae
40	<i>Stereospermum personatum</i> (Hassk.)	40	8	-	-	Bignoniaceae
41	<i>Syzygium cumini</i> (L.) Skeels #	152	18	-	-	Myrtaceae
42	<i>Terminalia labellerica</i> (Gaertn.) Roxb. #	24	6	64	12	Combretaceae
43	<i>Terminalia alata</i> (Heyne)Roth #	56	10	-	-	Combretaceae
44	<i>Walsura tabulata</i> Hiern #	24	6	40	8	Meliaceae
45	<i>Xerompis spinosa</i> (Thunb.) Keay	104	20	88	16	Rubiaceae
<b>Total</b>		<b>8656</b>	<b>732</b>	<b>9200</b>	<b>854</b>	

(0.34%) reported by Duwadee et al. (2006) of lower Arun River Basin, the value (0.28%) reported by Kandel (2007) in community managed forests of

Inner Terai and the value (0.13%) reported by Timilsina et al. (2007) in Sal forest of Western Terai. The high basal area in present study site resulted from

the presence of some large trees in girth size and stability of forests in the past.

The canopy cover in MCF forest category was higher than the LCF forest category, while litter cover was not significantly different between the two forest categories (Table 4). High canopy cover in MCF forest category is due to big-sized trees with high crown cover, while low canopy cover in LCF (less than 10 years) forest category is due to small-sized trees with low crown cover.

### Regeneration status of forest

Regeneration status of forests was assessed at three life forms, viz. seedling, sapling and tree. There were 55,900 seedlings ha<sup>-1</sup>, 8928 saplings ha<sup>-1</sup> and 1272 trees ha<sup>-1</sup> in the study area (Table 4). A population with a sufficient number of seedlings, saplings and young trees depicts satisfactory regeneration behaviour (Manna and Mishra 2017). It is an important component that demonstrates the developmental trend of the community, species composition and maintains the stability or sustainability of the forests in the future (Napit 2015). The diameter distribution of trees showed that each life form has a sufficient number of individuals to replace the number in its preceding life forms even after their mortality. According to Community forest resource inventory guideline (2004), regeneration status of the forest is said to be good if the forest has seedling > 5000 and sapling > 2000 per hectare (His Majesty Government [HMG] 2004, Pandey et al. 2012). As the regeneration of presently studied forest is in accordance with the above-mentioned criteria, we can say that these forests have good and satisfactory regeneration pattern. When the regeneration pattern of the present study was compared to other studies from Sal forests of Nepal (Paudyal 2013, DFRS 2014a, b, Napit 2015, Bhatta and Devkota 2020) and India (Adhikari et al. 2017, Raj 2018), regeneration is within the range of these studies. The combined effects of increased light intensity, reduced competition, low disturbances and low pH might have increased seedling recruitment and establishment in canopy gaps (more than 10 years forest category) compared to closed canopies (less than 10 years forest category). Thus, MCF forest category have better regeneration pattern as compared to LCF forest category. Similar to the

present study, Bhatta and Devkota (2020) found that seedling density was higher in forest stand with more age in comparison to less year's forest category.

### Size class distribution

The size class distribution diagram showed that the density of the trees with smaller girth size was higher than that of the larger girth size revealing reverse *J*-shaped structure in both forest categories and overall forest (Fig. 2). Tree distribution across different girth classes shows the capacity of resources utilization by the growing forest (Naidu and Kumar 2016). Higher stem density in lower girth class is due to the restriction of cutting of small-sized trees and suitability of existing environmental condition to trees, while lower stem density in higher girth class is due to the removal of large-sized trees (Sapkota et al. 2010). The higher density of trees with smaller girth size than that of the larger girth size also indicates the sustainable, stable and good regeneration state of forest (Basyal et al. 2011, Manna and Mishra 2017, Bhatta and Devkota 2020) with a good capacity of resources utilization (Naidu and Kumar 2016). A similar type of reverse *J*-shaped curve was also obtained by previous studies from Nepal and India, such as in the Sal forest of Rupandehi (Acharya and Shrestha 2011), Sal forest of Palpa (Basyal et al. 2011), Sal forest of Dadeldhura (Bhatta and Devkota 2020), hill Sal forest of Tanahun (Oli and Subedi 2015), Sal forest of west Bengal (Kushwaha and Nandy 2012) and Sal-dominated forest of west Bengal (Manna and Mishra 2017).

Soil of both forests under study was acidic in nature. The mean soil pH of MCF forest was 5.22±0.11 while that of LCF was 5.02±0.74 (Table 4). The mean soil nitrogen (N) content in MCF forest was 0.19±0.01% and in LCF forest was 0.16±0.01%. The average organic carbon (OC) content in the soil of the LCF forests was 2.89±1.05 compared to 3.46±1.28 in MCF forest. The average available phosphorus and potassium in the soil of LCF forest was 71.0±51.65 and 67.5±37.11 kg ha<sup>-1</sup>, respectively (Table 4). Similarly, average available phosphorus and potassium in the soil of MCF forest was 113.64±78.95 and 80.5±41.80 kg ha<sup>-1</sup>, respectively. Regeneration of forest was affected by different soil variables. Seedling growth is negatively related to nitrogen, pH and canopy cover ( $p < 0.05$ ). Growth

Table 4. Mean values of different variables and regeneration status studied in community forests of two developmental stages and overall study area (no. of plots;  $N = 100$ )

Variables	Management duration		T- value	p-value	Overall study area (mean±SE)
	MCF	LCF			
<i>Tree variables</i>					
Tree Density (plants ha <sup>-1</sup> )	1314±302	1230±324	-0.944	0.348	1272±313
Shrub density (plants ha <sup>-1</sup> )	8656±1888	9200±2086	2.33	0.022	8928±1987
Total density (plants ha <sup>-1</sup> )	10430±2190	9970±2410	6.209	0.000a	10200±2300
Sal tree density (plants ha <sup>-1</sup> )	638±321	708±342	-0.693	0.490	673±331.50
Tree basal area (plants ha <sup>-1</sup> )	9.874±1.23	7.508±1.46	0.782	0.364	8.69±1.34
<i>Stand variables</i>					
Canopy Coverage(%)	70.6±12.1	68.6±13.01	0.793	0.430	69.60±12.55
Litter Coverage (%)	67.9±13.4	67.61±12.62	0.115	0.909	67.75±13.01
Tree species richness (per 100 m <sup>2</sup> )	4.2±2.08	4.04±2.04	0.532	0.596	4.12±2.06
Shrub species richness (per 25 m <sup>2</sup> )	6.34±2.97	6.82±2.99	-0.804	0.423	6.58±2.98
<i>Soil variables</i>					
Soil Organic Carbon	3.46±1.28	2.89±1.05	2.42	0.017	3.17±1.16
Soil pH	5.22±0.11	5.02±0.74	1.485	0.141	5.12±0.425
Total nitrogen (%)	0.19±0.008	0.16±0.006	2.879	0.005	0.175±0.007
Soil Potassium (kg/ha)	80.5±41.80	67.5±37.11	1.65	0.002	74.0±39.45
Soil Phosphorus (kg/ha)	113.64±78.95	71.0±51.65	3.19	0.103	92.32±65.30
<i>Regeneration status</i>					
Seedling density (pl/ha)	58,400 ±1200	53,400 ±1380	-4.06	0.000a	55900±1290
Sapling(pl/ha)	9200 ±210	8656 ±213	-4.56	0.000	8928±211.5
Tree density (pl/ha)	1230±45	1314±18	-0.944	0.348	1272±31.5

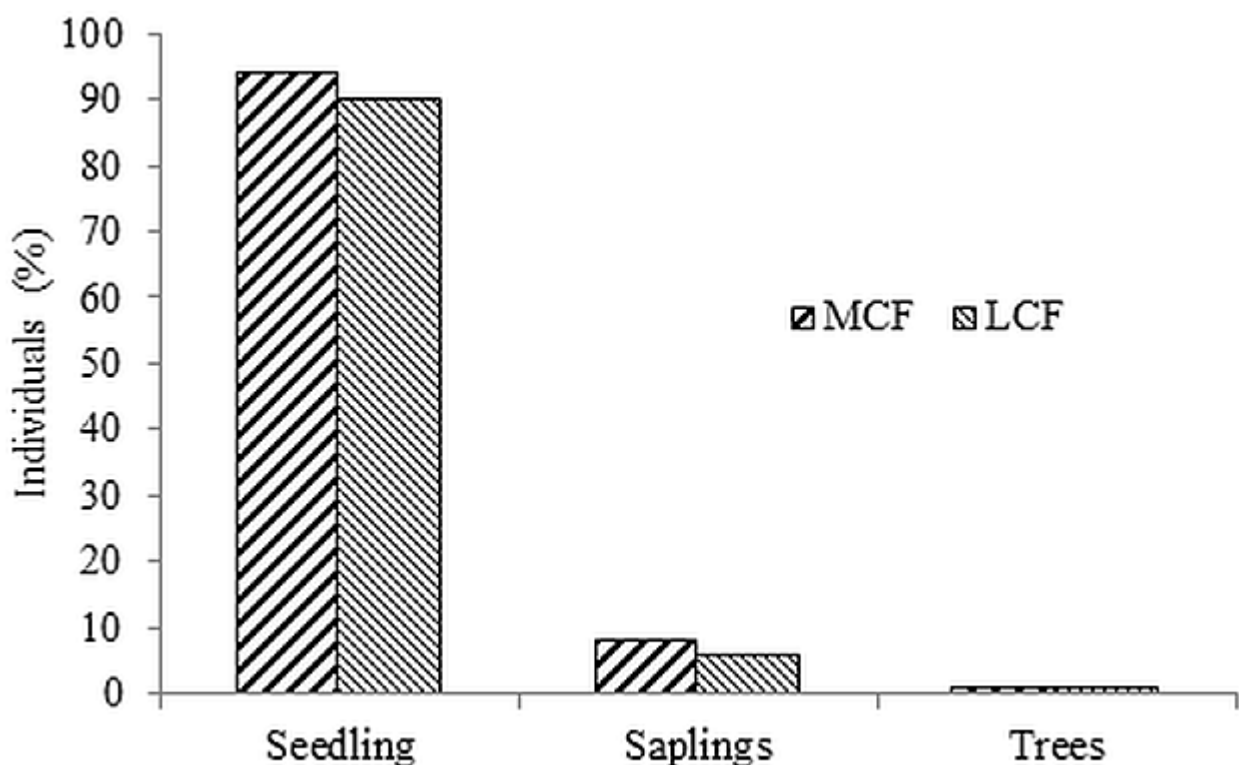


Figure 2. Percentage of trees, sapling and seedling of Sal population in MCF and LCF forests

of seedlings, saplings and trees were not related to soil organic carbon, potassium, phosphorus, ground vegetation cover and litter cover ( $p > 0.05$ ) (Table 5). Chauhan et al. (2010) observed the significant impact of soil parameters on seedling and tree density in the planted and natural Sal forest of India.

### Diversity indices

Tree species richness was higher in MCF forest in comparison to LCF forest while shrub species richness was higher in LCF forest than in MCF forest (Table 6). Since total density of plants was higher in MCF forest than LCF forest, species diversity was also higher in MCF forest. Significant positive correlation of tree density and diversity index was also reported by Sagar and Singh (2006) in disturbed dry forest of northern India. Information on diversity as a baseline information is required for proper management of community forest. The decrease in species diversity as a result of decline in less common species makes the ecosystem less stable. Diversity is a prerequisite for ecosystem stability (McCann 2000). However, both of these forests had lower

species diversity than the natural forest (2.3) in terai region, Nepal (Webb and Sah, 2003) and by Chauhan et al. (2010) for natural (3.53) and planted forests (3.26) in the Terai-Bhabhar of Sohagibarwa Wildlife Sanctuary, India. Khumbongmayum et al. (2005) reported Shannon diversity index ( $H'$ ) ranging from 1.79 to 3.17 and 1.89 to 2.25, whereas values for Simpsons Index ( $C_d$ ) varied between 0.07 to 0.59 and 0.11 to 0.16 for trees, and shrubs, respectively in four sacred groves of Manipur which are in support of present study. Jaccard's and Sorensen's similarity indices were higher in shrubs than in trees (Table 6). Tree diversity in both forests was less than other Sal forests of Nepal since high priority has been given for conserving Sal. Tree species diversity in CFs depends on the forest management activities of the community members who are managing that particular forest. During silvicultural operation, local people tend to remove useless species that alters species richness. Therefore; community forest should give priority for the conservation of species diversity during management activities.

Table 5. Spearman's correlation coefficient between different variables measured in the sample plots and regeneration (no. of plots;  $N = 100$ )

	SOC	Total N	Available P	Soil pH	Available K	CC	LC
Seedlings	0.430	-0.20 <sup>a</sup>	-0.12	-0.21 <sup>a</sup>	-0.14	-0.25 <sup>a</sup>	0.056
Saplings	0.013	-0.112	0.011	-0.156	0.004	-0.131	0.012
Trees	0.009	-0.021	-0.173	0.136	0.067	-0.112	-0.14

SOC = soil organic carbon; CC = canopy coverage; LC = Litter coverage; <sup>a</sup> Represents significant correlation ( $p < 0.05$ )

Table 6. Diversity parameters across study sites

Plant habit	S		C		H'		IS <sub>J</sub> %	IS <sub>S</sub> %
	LCF	MCF	LCF	MCF	LCF	MCF		
Tree	28	31	0.32	0.299	1.85	1.94	43.75	71.186
Shrub	42	39	0.316	0.342	2.044	1.98	62	76.54

S - Total number of species), C - Simpson's index of dominance, H' - Shannon-weiner index, IS<sub>J</sub> - Jaccard's similarity Index and IS<sub>S</sub> - Sorensen's similarity index (for < 10 years forest (LCF) and > 10 years forest (MCF).

### CONCLUSIONS

Total tree density varied with the management duration of the forest. The total tree density of community forest managed for more 10 years (MCF) forest was higher than the community forest managed for equal or less than 10 years (LCF) forest. The results suggest that the size class distribution of the trees resembling inverse-J shaped indicates the good regenerating capability of both forests. Tree species diversity in CFs depends on the forest management activities of the community members who are

managing that particular forest. Similarly, regeneration was mainly influenced by species richness, canopy cover and soil property. Forest condition and regeneration were directly associated with the developmental stage of forest. The study found that community forest has contributed to high tree species diversity where forest management communities have interests in multiple species, but most community forests are moving toward promoting limited timber yielding species that have high economic value.

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**Authors' contribution:** AD conceptualized and designed the study; PP collected and analyzed data, and prepare first draft of the manuscript; AD revised and finalized the manuscript.

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