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Urban forestry in the federal context of Nepal

With rapid urbanization throughout the world, urban and peri-urban forestry (UPF) has become a priority area for policy makers and development planners.UPF simply refers to the management of trees, shrubs and other vegetation in urban areas. It includes urban parks and gardens, roadside plantations, trees along the banks of rivers, streams and canals, surrounding houses and private properties and forests in peripheral of urban areas. UPF is valued for its psychosocial, cultural, environmental and economic benefits to the urban dwellers. It is regarded as the symbol of civilization and prosperity of any city.

The concept of UPF was emerged worldwide in response to the adverse environmental effects due to increased urban population and infrastructure. In Nepal, the practice of urban forestry dates back to the Malla reign. A review of historical documents reveals that King Jayasthiti Malla (1380-1395 AD) issued an order to his officials and commoners to plant trees alongside walking streets and wells. This practice continued; and even some exotic trees were planted alongside streets and in the premises of palaces in the Rana regime. During the Panchayat regime, the government introduced modern urban-environment planning in the 1960s and 1970s, and renovated roads and trails in Kathmandu with massive plantation along the sides. For example, the plan of the ring road had included green belts on both sides, where thousands of fast growing trees were planted. Now, the government has emphasized urban forestry through its various programs, including 'Nepal Clean Environment Grand Expedition 2075 AD' and the 'Forest Decade Program (2014-2023), the latter promoting afforestation in public and private lands with the theme of 'one house: one tree, one village: one forest and one town: several parks'.

Despite several efforts as mentioned above, we have not been much successful to achieve expected results in UPF development, mainly due to three reasons. First, most cities have been built haphazardly and in a piece meal approach, rather than through planned and holistic approaches. With rapidly growing prices of land in the urban areas, the private interests have played a key role in city planning; and spaces for trees have been rarely considered. Second, the open spaces like riverbanks and other public lands, in which urban forests could be developed, have been encroached for gray infrastructure. Third, the distinct values of forests in and around urban areas have been hardly recognized; *i.e.* no specific policies and plans have been in place for the management of urban and peri-urban forests. These have resulted in what we see and feel while living in crowded and polluted cities like Kathmandu today.

With the promulgation of the Constitution of Nepal in 2015, the nation has adopted the federal system of governance. The federal structure includes three tiers of government, *i.e.*

a federal government, seven provincial governments, and 753 local governments. The local governments include 6 metropolitan cities, 11 sub-metropolitan cities, 276 municipalities and 460 rural municipalities. The first elected governments are functioning in all the three tiers of governance. Sustainable development, in which protection of environment is one of the key considerations, is the main goal of the governments in all levels. In the context of rapid urbanization, developing and managing urban and peri-urban forests are one of the key functions of local governments, particularly metro/sub-metropolitan cities and municipalities. It will also address at least a part of fundamental right of every citizen to live in clean environment as ensured by Constitution of Nepal.

The local governments have both opportunities and challenges for UPF in their territories. There could be little room for developing UPF in the already crowded cities with narrow roads and limited open spaces like Kathmandu, but there are ample opportunities for the new municipalities. The only thing they need to do is to introduce holistic urban plans, consisting of parks, gardens, and green belts along the roadsides and riverbanks, and implement them strictly. One of the main challenges they would face is the fragmentation of lands coupled with their high prices; this can be addressed through a land pulling mechanism as we have already experienced in city planning in some areas around Kathmandu. Not Planting trees now would not be a big issue, but not having a space for planting trees would be a very big issue for our cities in the future.

Natural regeneration potential and growth of degraded *Shorea robusta* Gaert n.f. forest in Terai region of Nepal

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Sal *(Shorea robusta)* has ecological, economical and socio-cultural importance. It is a dominant species in the Terai and Chure region of Nepal. Natural regeneration is the only relevant regeneration method for Sal in Nepal. This study intended to assess natural regeneration potential of Sal in ploughed and unploughed (control) sites. The study was carried out in Chetaradei of Kapilvastu district in an area of 4.79 ha. Two treatments (control and ground work *i.e*. ploughed) were applied to assess regeneration potential of Sal. The radius of the sample plots was 2 m, which were laid out systematically and the data were recorded from these plots in three consecutive years. Regeneration density was found higher in control site than ploughed site. T-test for regeneration density in three consecutive measurements showed that there was no significant difference between ploughed and unploughed conditions. The species composition was dominated by Sal in both ploughed and unploughed sites. Species diversity (Shannon Weiner) index was found higher in ploughed site than unploughed site in three consecutive measurements. Moreover, T-test showed that mean height of Sal was not significant in both ploughed and unploughed sites except in the first measurement. This study shows that protection from grazing and fire is essential for natural regeneration of Sal. However, ground work helps to increase tree species diversity but it is not necessary in degraded Sal forest.

Keywords: Ground work, Kapilvastu, plough, treatment

Sal (*Shorea robusta*) forest is one of the 35 different forest types found in Nepal (Stainton, 1972). It is a dominant species, shares 54.77% and 48.64% of the total stem volume in Terai (DFRS, 2014a) and Chure (DFRS, 2014b) regions, respectively. It is mainly valued for strong and durable construction timber but used as fuel and fodder as well (Jackson, 1994). Multiple product management for Sal is essential from social, economical and ecological perspective (Gautam and Devoe, 2006).

Natural regeneration is the only relevant regeneration method for Sal in Nepal (Joshi *et. al*., 1995). Although many known and unknown causative factors affect the process of natural regeneration, the major factors include climate, soil, seed, biotic conditions, etc. (Singh *et al.*, 1987); and soil moisture and light intensity (Tyagi *et al*., 2011). However, Sal forests in Nepal are shrinking with poor regeneration and there is change in species composition as well (Sapkota *et al*., 2009) which is a challenge for Sal forest management.

Variation in species composition, regeneration status and diversity in Sal forest is determined by altitude, climate and edaphic factor (Uma, 2001). In order to know the regeneration potential of Sal in degraded Sal forest, studies have been conducted in different parts of the country. However, these studies are limited to assess regeneration potential and growth of Sal only under different thinning regimes in different forests system (high forest, coppice forest) without ground work (*i.e.* exposure of soil). Soil working facilitates seed to grow due to easy aeration and nutrient uptake as compared to a compact soil. Soil compaction typically decreases absorption of major mineral nutrients, especially N, P and K by roots (Kang and Lal, 1981) resulting in growth inhibition such as parks and golf courses (Davis, 1952; Lunt,

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1956) and timber harvesting areas (Youngberg, 1959, Sands and Bowen, 1978).

In this regard, this study was carried out to assess regeneration potential and growth of Sal forest in ploughed and unploughed sites in Terai region, which is different from previous studies. Thus, the study intended to know the effect of exposure of soil in natural regeneration potential and growth of Sal.

Materials and methods

Study area

The study was carried out in Tilaurakot collaborative forest. It lies in Chetaradei of Kapilvastu district (Fig. 1), approximately 15 km to the south of the Mahendra Highway near to Gorusinghe bazaar. The study site was established in 2013.

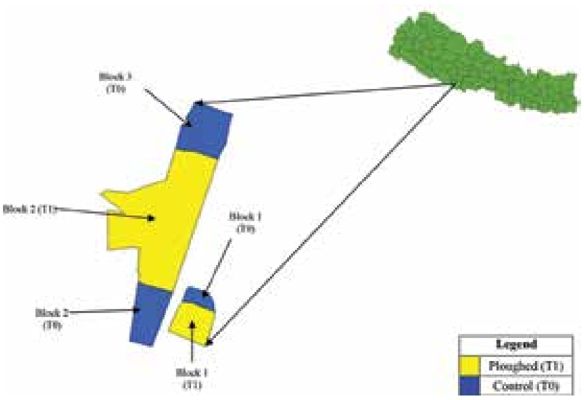


Fig. 1: Map of the study area with allocation of treatments in Kapilvastu district

Condition of the study area

The whole site was clear felled except maintaining few mother trees to promote regeneration. Dispersal of seeds from the mother trees was enough to cover the extent of the study area as seeds disperse approximately 100 m away by wind (Jackson, 1994). Before the treatments applied, the site was absence of Sal regeneration. It was supposed to be very difficult to regenerate Sal without any intervention. Thus, the site was ploughed using Tractor assuming that there would be regeneration. The whole site was fenced and guarded to protect Sal regeneration from grazing and fire.

Research design

Ploughing was done in two blocks of the selected site whereas three blocks of the site were treated as control (Fig. 1). The detail of the research design is given in table 1.

Circular sample plots had 2 m radius and were spaced systematically. Spacing between the plots was 30m x 30 m for ploughed site and 20m x 20m for unploughed (control) site. Altogether, 50 and 41 sample plots were employed in ploughed and unploughed sites, respectively (Table 1).

Data collection

For the study, regeneration of Sal includes both seedling (height <1m) and sapling (height>1m and dbh<10 cm). Recorded variables were species, its frequency and height. The first data collection was carried out after three years of establishment of the research plots and continued for another two years.

Data analysis

The data analyses included estimation of regeneration/ha, mean height, species diversity in ploughed and unploughed sites and comparison of

Table 1: Research design used in the study

S.N	Treatment	Block	Area (ha)	Number of sample plots	Remarks
1	Control (T0)	1	0.24	4	Sample plot spaced between 20m x 20 m
		2	0.95	11	
		3	1.17	26	
2	Ploughed (T1)	1	0.74	6	Sample plot spaced between 30m x 30m
		2	4.79	44	

the regeneration potential of Sal between these sites using tabular form. Statistical test (*i.e.* T-test) was also performed to know the significant distribution of the target variables in different conditions.

Limitations

The study was based on the data of three years only. The trend showed by the variables may not follow the same pattern in future. The study site was not completely well drained and of profuse growth of weeds. Hence, findings of this study may not be generalized.

Results and discussion

Regeneration density Status of regeneration (seedlings and saplings) in terms of number per hectare determines the condition of the forest. Most of the regeneration were seedling (height up to 1m) whilst few were saplings (height >1m). Thus, the density of seedlings was higher than the density of saplings in all the measurements (Table 2).

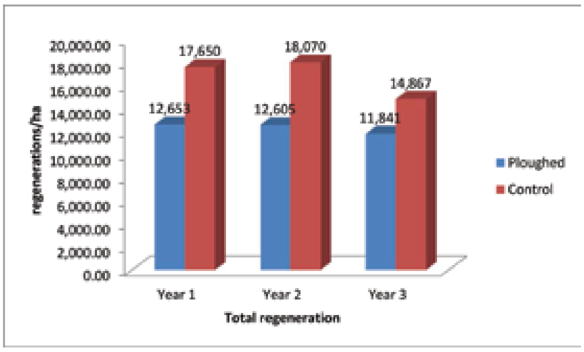


Fig. 2: Regeneration density (number per ha) in ploughed and unploughed sites

Similarly, regeneration density of Sal was found to be decreasing in both ploughed and unploughed sites in three consecutive measurements (Fig. 3). Particularly, the rate of decrease in Sal regeneration in three consecutive measurements was higher in ploughed site (66.91%, 54.54% and 51.61%) than the unploughed site (68.61%, 61.97% and 65.14%). The regeneration density of Sal was higher in unploughed site (Fig. 3).

Table 2: Density of seedlings and saplings in ploughed and unploughed (control) sites

Description	Treatment	M1 (/ha)	M2(/ha)	M3(/ha)
Seedling	Ploughed	11,682 (1407)	8,992 (1153)	7,353 (930)
	Control	15,741 (2825)	13,159 (2414)	10,656 (1969)
Sapling	Ploughed	971 (304)	3,613 (634)	4,488 (677)
	Control	1,048 (216)	4,910 (899)	4,212 (594)

Note: Standard error in parenthesis, and M1=First measurement, M2= Second measurement, M3= Third measurement

Regeneration of *Shorea robusta* shared major portion in the study area, which was followed by more than 20 different tree species such as *Syzygium cumini*, *Sapium insigne* (Dudhekhirro), *Mallotus philippinensis*, etc. In this study, regeneration density (in terms of total number of seedlings and saplings/ha) was found to be decreasing in three consecutive measurements in ploughed site while the trend was not similar in the control site. Regeneration density was higher in unploughed site than ploughed site in all the three consecutive measurements (Table 2). The difference in regeneration density was gradually being filled uptill the third measurement (Fig. 2).

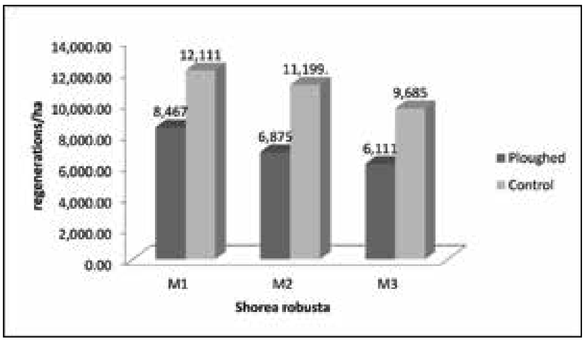


Fig. 3: Regeneration density of Sal in ploughed and unploughed sites

However, t-test for regeneration density in three consecutive measurements (i.e. p-value of 1st measurement = 0.2123, 2nd measurement = 0.1662 and 3rd measurement = 0.6471) showed that there was no significant difference between ploughed and unploughed sites. The t-test result was also the same for particularly Sal regeneration *(i.e.* p-value of 1st measurement = 0.2662, 2ndmeasurement =0.0709 and 3rd measurement = 0.0832).

Number of natural regeneration can help classify the condition of forest. In general, more the regeneration, better the forest condition. Good regeneration always remains a key for the sustainable forest management. In this study, regeneration was lower (just exceeded 18,000) than other studies conducted by Rautiainen and Suoheimo (1997), DFRS (2014a) and Ranabhat *et.al.* (2016). These studies were done in Sal forest including different stages of trees (*i.e.*, tree, pole, sapling and seedlings) and/or complete removal of weeds but this study was carried out in the degraded area with problem of regeneration. Besides this, some portion of the study area was water logged and the area was dominated by the grasses and weeds, hence the regeneration was lower than other sites.

In particular, regeneration of Sal is decreasing abruptly in the ploughed condition than control condition. In ploughed condition, soil is exposed which is good for aeration and nutrient uptake for plants compared to compact soil (Kang and Lal, 1981). This condition is suitable for plants to grow. Besides Sal, ploughed condition welcomes other tree species also to regenerate which ultimately helps in declining the density of Sal regeneration.

Species diversity

Species diversity is one of the major indicators for the status of forest ecosystem. Terai forest has diversity of tree species, where Sal is a major tree species associated with many other tree species. Species diversity was found higher in ploughed site than unploughed site (Annex 1). Altogether, 17, 19 and 23 regeneration species were found in ploughed site in three consecutive measurements whilst 14, 16 and 20 in unploughed site in the same measurements. Similar results were found in case of seedlings and saplings when analyzed separately. However, in both ploughed and unploughed sites, the number of species was found to be in an increasing trend in later measurements (Table 3).

Table 3: Total number of regeneration species in three consecutive measurements

Description	Treatment	1st measurement	2nd measurement	3rd measurement
Regeneration	Ploughed	17	19	23
	Control	14	16	20
Seedling species	Ploughed	15	17	18
	Control	10	13	17
Sapling species	Ploughed	12	17	18
	Control	13	15	15

Total regeneration was higher in the unploughed site than ploughed site until the 3rdmeasurement. But, the difference in regeneration is gradually being narrowed with the elapse of time. By ploughing the land, it could disturb the soil to grow plant for few years and also kills the plants already existed there. Thus, regeneration density becomes lower for few years in ploughed condition than control condition. Once the soil becomes suitable for plants to regenerate, the regeneration process accelerates more in the ploughed condition.

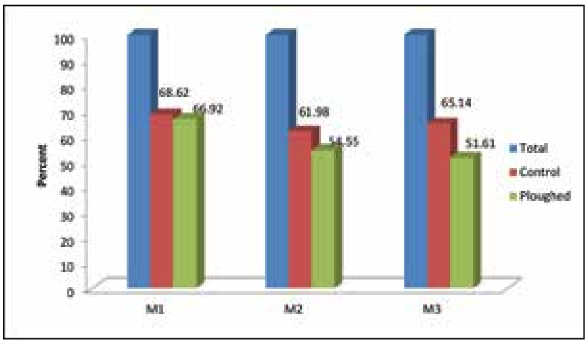
The value of Shannon Weiner diversity index was higher in ploughed site (*i.e.* 1.4, 1.56 and 1.75) than unploughed site (*i.e.*, 1.00, 1.4 and 1.4) in three consecutive measurements. It indicates that the possibility of increase in species diversity is higher in ploughed site than unploughed site.

The regeneration diversity found in this study (14 to 23 species) is more or less the same to the findings of (Ranabhat *et. al.,* 2016 ; Sapkota *et al.*, 2009), though research sites condition were different. The tree species diversity at the seedling stage was higher than that of sapling stage in both ploughed and unploughed sites. Similar findings were reported in previous studies (Ranabhat *et al*., 2016; Sapkota *et al.,* 2009). However, regeneration density was found to be higher in the ploughed site than unploughed site. Ploughed condition offers conducive environment for many species for regeneration, which may be one of the reasons of high species diversity. All the seedlings may not reach at the sapling stage due to adverse condition, which leads to reduction in species diversity at the sapling stage.

Species composition

Composition of species was dominated (in terms of frequency) by Sal in both ploughed and unploughed sites. It represented more than half of the total regeneration. Sal dominates in the forestsof Terai and Chure regions of Nepal by 32.25% (DFRS, 2014a) and 30.42% (DFRS, 2014b), respectively. The same results are reported by (Giri *et al*., 1999;Paudyal, 2013; Acharya *et al*., 2009 and Sapkota, *et al*., 2009). However, domination of Sal was higher in unploughed site than ploughed site. After Sal, domination of other species was found different in both ploughed and unploughed sites (Annex 2).

In general, the domination of Sal was found to be decreased in both ploughed and control plots in three consecutive measurements (Fig. 4). It shows that the share of other species increased every year. However, domination of Sal was found to be decreased more in ploughed site than unploughed site (Fig. 4). Result shows that the chance of regeneration of other species in the Sal dominated area is higher when it is ploughed.



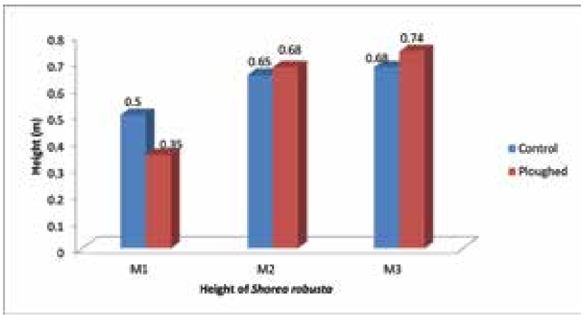
Note: M1=First measurement, M2= Second measurement, M3= Third measurement

Fig.4: Domination of Sal in three different consecutive measurements

Height growth

In the first measurement, mean height of Sal was found to be higher in the unploughed plots. Contrastingly, second and third measurements showed opposite results (Fig. 5). The presence of some Sal regeneration in control plots during establishment might have caused to increase height growth in the first measurement.

Result shows the rate of height growth is higher in ploughed site than unploughed site. However, T-test showed that mean height of *S. robusta* was not significant in both ploughed and unploughed sites except in the first measurement (p1=3.45e-15, p2=0.5494, p3=0.2404).



Note: M1=First measurement, M2= Second measurement, M3= Third measurement

Fig.5: Mean height of Sal in three consecutive measurements

In the favorable condition, height growth of Sal is fast in the initial (regeneration) stage up to 6m after five years from the seed (Jackson, 1994). Height of the regeneration of Sal increases more in the absence of shelter trees (Rautiainen and Suoheimo, 1997). Result of the study shows that ploughed condition is more favorable to height growth of Sal compared to normal condition. However, the result is opposite to the general findings i.e. as height of tree increases as it grows in dense. But, exposure of soil helps in nutrient uptake and good aeration which may be the reason to increase the height of Sal irrespective of its density.

Conclusion

It is well documented that degradation of Sal forests is the result of heavy grazing, lopping and fire. The degraded condition of the Sal forest can be enhanced to the similar condition of the good natural forest in long run if it is conserved well (Ranabhat *et al*., 2016). The satisfactory results of regeneration have been achieved even in the degraded area in this study. Thus, it is clear that protection from grazing and fire is the foremost requirement for regeneration of Sal.

Tree species diversity can be maintained in the degraded Sal forest area. However, ground work (*i.e.* exposing soil) is necessary to increase tree species diversity at the cost of losing the dominance of Sal species. Similarly, ground work also supports to increase height growth of Sal regeneration.

All the studied variables (such as regeneration density, species diversity, height growth) do not differ significantly in the ploughed and unploughed sites until the five years of establishment. The result shows that the impact of the ground work (*i.e.* complete ploughing using machine) is ineffective to bring substantial differences in the growth of Sal regeneration and species diversity but increases cost of management. Based on this study, it can be concluded that complete ground work using machine in degraded Sal forest may not be an essential task for Sal forest management from both ecological and financial point of view. However, complete protection from grazing and fire seems foremost tasks to manage degraded Sal forest in the Terai region.

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Annex 1: Tree species in ploughed and unploughed (control) sites

S.N.	Latin name	Local name	Control (T0)	Ploughed (T1)
1	*Shorea robusta*	Sal	√	√
2	*Terminalia alata*	Asna	√	√
3	*Dalbergia sissoo*	Sisso	√	√
4	*Acacia catechu*	Khair	---	√
5	*Azadirachta indica*	Neem	√	---
6	*Syzygium cumini*	Jamun	√	√
7	*Sapium insigne*	-	√	√
8	*Mallotus philippinensis*	Sindure	√	√
9	*Terminalia belerica*	Harro	---	√
10	*Aegle marmelos*	Bel	√	√
11	*Psidium guajava*	Amba	√	---
12	*Pterocarpus marsupium*	Bijaysal	---	√
13	*Diospyros melanoxylon*	-	√	√
14	*Schleichera oleosa*	Kusum	√	√
15	*Holarrhena pubescens*	-	√	√
16	*Dalbergia latifolia*	Sati sal	---	√
17	*Careya arborea*	-	---	√
18		Kachari	√	√
19		Ghurmusrani	√	√
20		Tikuli	---	√
21	*Terminalia chebula*	-	---	√
22	*Myrsine semiserrata*	-	√	√
23	*Ficus glomerata*	-	√	---
24	*Lagerstroemia parviflora*	Botdhairo	√	√
25	Unknown1	-	---	√
26	Unknown2	-	---	√
27	*Artocarpus lakoocha*	Katahar	√	---
28	*Leea crispa*	-	√	---

Annex 2: Composition of ten major species in three consecutive measurements

SN	Latin name	Composition (%) Control (T0)			Latin name	Composition (%) Ploughed plots (T1)		
		M1	M2	M3		M1	M2	M3
1	*S. robusta*	68.62	61.98	65.14	*S. robusta*	66.92	54.55	51.61
2	*S. cumini*	14.43	10.63	7.18	*M. philippninensis*	7.38	7.83	6.59
3	*M. philippninensis*	4.15	3.87	5.22	*S. insigne*	5.98	0.88	4.7
4	*S. oleosa*	4.38	3.44	3.13	*T. belerica*	3.43	3.54	3.23
5	*P. marsupium*	1.73	1.29	2.48	*P. marsupium*	3.31	4.42	4.97
6	*H. pubescens*	0.92	8.81	9.5	*S. oleosa*	3.31	2.27	3.49
7	*S. insigne*	0.23	6.66	2.35	*A. marmelos*	3.18	1.77	2.02
8	*A. marmelos*	0.57	1.18	0.65	*H. pubescens*	1.27	19.44	16.94
9	*T. alata*	0	0.64	0.91	*S. cumini*	1.4	1.14	1.08
10	*P. guajava*	0.34	0.32	0	*A. catechu*	0.76	0	0

Note: M1=First measurement, M2= Second measurement, M3= Third measurement

Comparative study on litter production and nutrient return to soil in Tarai and Hill Sal (*Shorea robusta* Gaertn.) forests of eastern Nepal

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Litter production and nutrient return to soil through litterfall is important pathway for the regulation of nutrient cycling and primary production of the forest. Litterfall dynamics is generally influenced by phenology of tree species, seasons and altitude of the forest stand. As most of the information on litter production are from temperate and dry tropical region. A comparative study on litter production and nutrient return were conducted in Terai Sal forest (TSF) and Hill Sal forest (HSF) located in moist tropical region of eastern Nepal. Litter samples were collected from the litter traps (1m × 1m size) placed randomly in the forest. Collection was done at two months interval for one year. Annual litterfall in TSF (8.82 Mg $ha^{-1}y^{-1}$) was significantly ($p < 0.001$) higher than in HSF (7.18 Mg $ha^{-1}y^{-1}$).There was distinct seasonality in litter production. In TSF and HSF, litterfall was maximum in the summer (6.57 Mg ha^{-1} and 5.05 Mg ha^{-1}, respectively) and minimum in winter season (0.86 Mg ha^{-1} and 0.72Mg ha^{-1}, respectively). Amount of nutrient return to forest soil through litterfall (kg ha^{-1} y^{-1}) was higher in TSF (72.44 N, 6.80 P and 33.23 K) than HSF (54.31 N, 4.84 P and 22.23 K). The difference in litter production between these two forests was influenced by the phenology of dominant tree species, variation in altitude and seasons. Nutrient return through litterfall is a great input of nutrients in soil which is required for production process. Thus, litter constitutes a significant role in forest management.

Key words: Hill Sal forest, litterfall, nutrient return, seasonal variation, Tarai Sal forest

Plant litter production and its decay are the two important processes which provide the main input of organic matter in soil and regulate the patterns of nutrient cycling in forest ecosystems. Litterfall reflects primary productivity which represents approximately 30% of annual production and characterizes a major proportion of forest carbon fluxes (Macinnis-Ng and Schwendenmann, 2014). It is a central nutrient resource in tropical forest ecosystems where soils are generally nutrient poor and highly weathered (Maritus *et al*., 2004). So, litterfall is an important pathway of nutrient succession which preserves soil fertility in forest ecosystems (Bellingham *et al*., 2013).

Litterfall compilation is a standard non-destructive method for assessing the productivity and turnover of organic matter in a forest. Therefore, determining the dynamics of litterfall and nutrient return to the soil through it with time is a fundamental aspect of functioning of terrestrial ecosystem (Maritus *et al*., 2004). Litterfall dynamics in the natural forest ecosystems is strongly influenced by species composition (Singh and Kushwaha, 2006), age structure (Stonhlgren, 1988), seasons (Sundharapandian and Swamy, 1999), altitude (Garkoti and Singh, 1995) and latitude (Bray and Gorham, 1964). Precipitation, temperature, radiation and soil features are also major controlling factors of litterfall in tropical forests where it occurs during the dry season (Zhang *et al*., 2014).

Litterfall exhibits distinct seasonality in different forest ecosystems and depends mainly upon the location and nature of plant species. Many deciduous species shed their leaves during

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the dry season (Elliott *et al*., 2006). Distinct seasonality occurs in sub-tropical mixed oak forest of northeastern India, where maximum litterfall takes place during November to March (Devi and Yadava, 2010). Zhang *et al*. (2014) documented the seasonal pattern of litterfall in forest ecosystems by collecting data from existing literature and concluded that the peak of litterfall in tropical forest was in drought season corresponding to spring or winter season. However, peak of litterfall could occur at various seasons in temperate broadleaved and needle-leaved evergreen forests, and peak of litterfall was observed in autumn in temperate deciduous broadleaved and boreal evergreen needle-leaved forests. From a large number of published and unpublished datasets across South American tropical forests, it is concluded that seasonality in litterfall was significantly correlated with the rainfall (Chave *et al*., 2010).

As the litter is the above ground source of nutrients, it helps to manage the nutrient cycling process for better forest production. Regarding the litterfall and its seasonality mostly the information are from dry tropics. Here, an attempt has been made to document the information from moist tropical region. The present study was carried out to answer the following questions. (I) What is the status of litter production in Tarai and Hill Sal forests ? (ii) Does seasonality affect the litter production in these forests ? (iii) What is the contribution of litter in providing the nutrients (N, P, K) to the soil in Sal forests?

Materials and methods

Study area

The study was carried out in Sal forest located in Tarai and Hilly regions of eastern Nepal. Sal forest of Tarai region is addressed as Tarai Sal forest (TSF) and Hilly region as Hill Sal forest (HSF). TSF is located at Jalthal near Kechana (extreme low land of Nepal) of Jhapa district. It occupies an area of 6300 ha. of land and lies in between 87° 55' and 88° 03' E longitude and 26° 27' and 26° 32' N latitude. The forest floor has uneven surface and topographical variation ranges from 62 to 129 m msl. HSF is located at Kiteni of Kolbung, Ilam district. The forest lies in sub-himalayan tract (Shiwaliks) at an altitudinal range of 500 to 850 m msl. The HSF is situated in between 88° 02' and 88° 04' E longitude and 26° 44' and 26° 47' N latitude (Fig. 1).

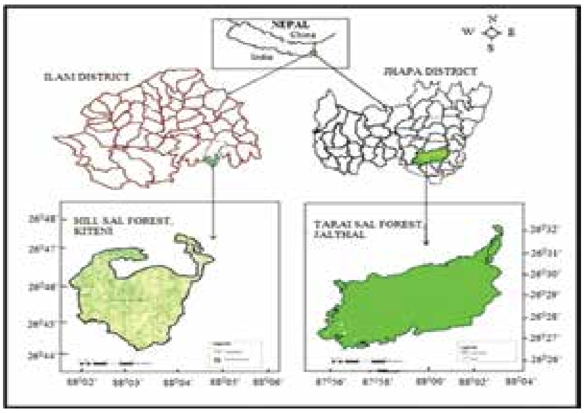


Fig. 1: Location of study area of Hill Sal forest at Kiteni, Ilam district and Tarai Sal forest at Jalthal, Jhapa district in eastern Nepal

The climate of the study area is tropical monsoon type. Based on the data pertain to the period, 2001— 2014, the mean monthly minimum temperature of TSF ranged from 10°C to 24°C and maximum temperature ranged from 23.9°C to 33.4°C (Fig. 2a). Likewise, the mean monthly minimum temperature of HSF ranged between 9.4°C to 19.9°C and maximum temperature between 16.4°C to 25.9°C (Fig. 2b). The average annual rainfall of TSF was 2130.4 mm and HSF was 1776.07 mm in which maximum rainfall (80 — 85%) occurred during rainy season.

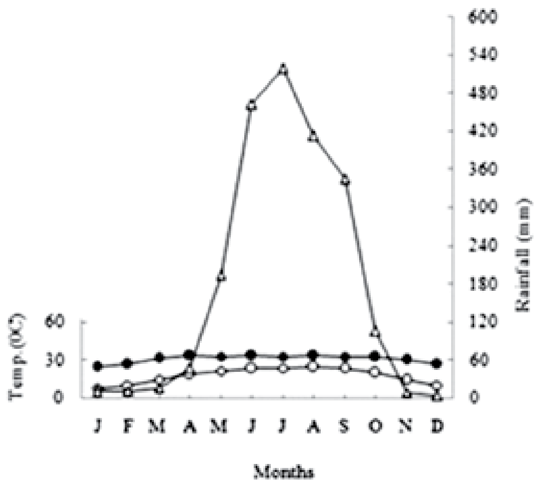


Fig. 2a: Ombrothermic representation of the climate the climate in Tarai Sal forest

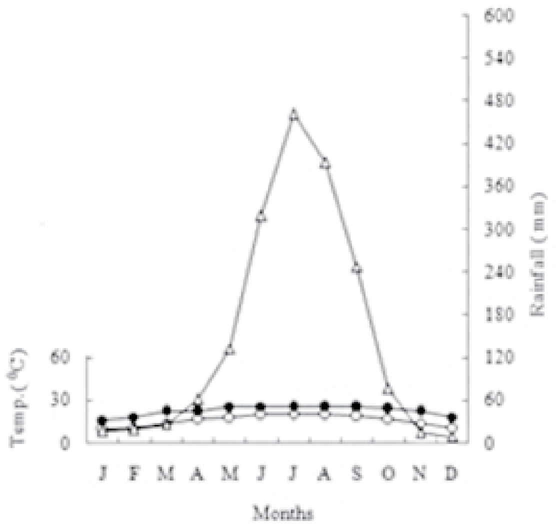


Fig. 2b: Ombrothermic representation of in Hill Sal forest

The temperature (-o-; mean monthly mimimum and-●-; mean monthly maximum) and-Δ-; rainfall data pertain to the period, 2001—2014.

Both TSF and HSF (tropical moist forest according to the life zone classification of Holdridge *et al*., 1971) are dominated by *Shorea robusta* Gaertn. The main associated species like *Lagerstroemia parviflora* Roxb*., Dillenia pentagyna* Roxb*.,* and *Schima wallichii* D. C Korth are common in both forests. All these species are summer deciduous (Gautam, 2015). However, TSF is peculiar in containing *Artocarpus chaplasa* Roxb. and sub-tropical species like *Castanopsis indica* (Roxb.) Miq, *Michelia champaca* Land *Madhuca longifolia* (Koenig) Mac. Soil of TSF is Sandy loam Mollisols which has dark top soil. In the HSF, soil is Sandy loam Entisols with much gravel, stones and rock fragment (Jackson, 1994).

Estimation of litter fall

The inner core area in each forest stand (TSF and HSF) was divided into 100 grids each having 100m ×100m size. Among them 30 grids were selected randomly for the study purpose. Selection of grids was done alternately in clockwise direction for periphery to centre. Within each selected grid a permanent plot of 20m × 20m was fixed. Sampling plot was fixed in three ways e.g. at upper, middle and lower portion of the grids in each forest.

Litter fall samples were collected from the litter traps. One litter trap (1m × 1m size) was fixed in each plot. Within the thirty plots in each forest the litter traps were located near the trees, far from the trees and between the trees. Collection was done at an interval of two months for one year from March 2013 to February 2014. The collected samples were brought to the laboratory and separated into leaf and non-leaf (small branches, reproductive parts and miscellaneous) components. Litter samples were oven dried at 80ºC for 24 hours and the mean bi-monthly dry weight value for each forest was estimated. For the purpose of the chemical analysis, litter samples were mixed and pooled separately component wise in proportion to their volume to represent annual sample for each forest site. Pooled samples were stored in dried form in air-tight polythene bags for chemical analysis.

Chemical analysis of litter

The oven dried form of pooled samples of each litter component were ground separately and passed through 1mm mesh screen. Chemical analysis was done in triplicates for each litter component. The total nitrogen concentration was determined by micro-Kjeldahl method (Peach and Tracey, 1956). Using the method of Allen *et al*. (1974), 200 mg oven dried plant material was digested in 7 ml triacid mixture (5:1:1, nitric acid: sulphuric acid: perchloric acid), cooled and transferred on hot plate till the material changed to pink color and diluted to 100 ml by using triple distilled water. Using 5ml aliquot, ammonium molybdate and $SnCl_2$, the total P was determined by developing blue colour and with the help of spectrophotometer. Potassium was determined by atomic absorption spectrophotometer.

Statistical analysis

Statistical tests were carried out in SPSS (IBM Statistics, ver. 20) packages. The data were checked for normality (Kolmogorov-Smirnov test) before statistical analysis. Two ways ANOVA was used to test the significant difference in the amount of litterfall due to forest types (TSF and HSF) and seasons.

Table 1: Annual litter fall (Mg ha^{-1} y^{-1}± 1 SE) in Tarai Sal forest and Hill Sal forest

Forests	Leaf litter	% of total	Non-leaf litter	% of total	Total
Tarai Sal forest	6.16±0.06	70	2.66±0.05	30	8.82±0.06
Hill Sal forest	5.01±0.12	70	2.17±0.08	30	7.18±0.19

Results and discussion

Litter production in TSF and HSF

Annual litterfall in TSF (8.82 Mg ha^{-1}y^{-1}) was higher than in HSF (7.18 Mg ha^{-1}y^{-1}) (Table 1).

ANOVA suggested that the variation in litterfall was significantly ($p < 0.001$) different for forest types (Table 2).

Table 2: Effect of forest sites, seasons and forest sites × seasons interaction in the litterfall in TSF and HSF as indicated by ANOVA.

Source of Variation	df	F	Significance
Forest	1	113.76	P<0.001
Seasons	2	4038.84	P<0.001
Forest × Seasons	2	96.45	P<0.001

Contribution of leaf litter was always higher (70%) than non-leaf litter (30%) in both forests. Leaves comprised the most important part of litterfall, as has been found for most of the forest ecosystems (Paudel *et al*., 2015; Wang *et al*., 2007; Yang, 2005; Martius *et al*., 2004; Arunachalam *et al*., 1998).

In the present study the higher litter production in TSF than HSF could mainly be due to differences in microclimate and soil properties which affect the productivity (Vitousek, 1984). As temperature declines with increasing altitude (Girardin *et al*., 2010), the decomposition process and nutrient supply became retarded due to which above-ground net production including litter production declined (Belligham *et al*., 2013; Kitayama and Aiba, 2002; Garkoti and Singh,1995).

Comparative account of litter production in some tropical and sub-tropical forests is presented in table 3. The value estimated for TSF was

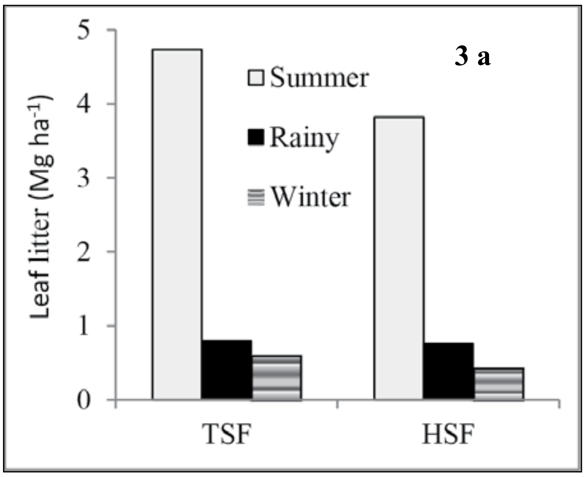
Table 3: Comparative account of litter production (Mg ha^{-1} y^{-1}) in some tropical and sub-tropical forests

Location	Forest types	Litter production	References
Nepal			
Jalthal, Jhapa	Tarai Sal forest	8.82	Present study
Kiteni, Ilam	Hill Sal forest	7.18	Present study
Charkoshe, Sunsari	Tropical moist Sal forest	11.8	Gautam, 2015
Panchakanya, Sunsari	Plateau Sal forest	10.3	Mandal, 1999
India			
Manipur	Sub- tropical Oak forest	10.94	Devi andYadaba, 2010
Kodiyar, Tamilnadu	Deciduous forest	5.76 - 8.65	Sundarapandian and Swamy, 1999
Kodiyar, Tamilnadu	Evergreen forest	5.63 - 7.84	Sundarapandianand Swamy, 1999
Vidhyan plateau	Dry tropical savannahs	2.8 - 5.9	Tripathi and Singh, 1995
Nanda Devi Reserve	Forests of Central Himalaya	4.22	Garkotiand Singh, 1995
Thrissur, Kerala	Moist deciduous	12.2 - 14.4	Kumar and Deepu, 1992
Mornihills, Haryana	Moist deciduous	10.4	Gupta and Raut, 1992
	Sal and mixed Sal forest	2.8 - 7	Sharma *et al*., 1990a, b
	Deciduous forest	1 - 6.2	Singh, 1968
Other counties			
China	Evergreen broad-leaved forest	3.28 - 11.26	Paudel *et al*., 2015
China	Global pattern	3.0 - 11	Zhang *et al*., 2014
New Zealand	Evergreen montane rain forest	2.81	Bellingham *et al*., 2013
South America	Tropical forests (n= 81)	8.61	Chave *et al*., 2010
China	Sub tropical forest	4.89 - 10.61	Zhou *et al*., 2007
China	Evergreen broad-leaved forest	4.63 - 8.85	Yang *et al*., 2005

comparable to Plateau Sal forest of Nepal (10.3 Mg $ha^{-1}y^{-1}$; Mandal, 1999) and moist deciduous forest of Moni Hills, Haryana, India (10.4 Mg $ha^{-1}y^{-1}$; Gupta and Raut, 1992). On the other hand the value obtained for HSF was comparable to tropical forests of South America (8.61 Mg $ha^{-1}y^{-1}$; Chave *et al*., 2010).

Seasonal variation in litter production

There was distinct seasonality in the pattern of litter production in both forests (Table 2). In TSF and HSF, it was higher in the summer season (6.57 Mg $ha^{-1}$and 5.05 Mg ha^{-1}) followed by rainy (1.39 Mg ha^{-1} and 1.41Mg ha^{-1}) and winter season (0.86 Mg ha^{-1} and 0.72 Mg ha^{-1}), respectively (Fig. 3). Environmental variables like temperature and rainfall greatly influence the seasonal pattern of litter fall in tropical forests (Zhang *et al*., 2014; Chave *et al*., 2010). High temperature during summer season reduces the humidity and increases the rate of transpiration which enhances the rate of litter fall (Twilley *et al*., 1986).



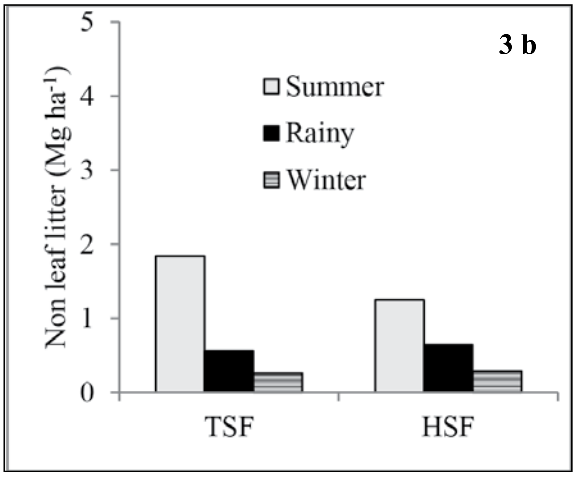


Fig. 3 a & 3 b: Seasonal variation in litterfall (Mg ha^{-1}) in Tarai Sal forest and Hill Sal forest of eastern Nepal. Seasonal representations are as: Summer (March-June), Rainy (July-October) and Winter (November-February).

Nutrient return through litter fall

Nutrient concentration of different components of litter was slightly higher in TSF than HSF as summarized in table 4. Concentration of nutrients in different litter components in diminishing order was: N>K>P in both forests. Nutrient concentration in leaf litter was nearly 1.5 times higher than the non-leaf litter in each forest. Generally, the woody litter has lower N and P concentration than the foliage (Arunachalam *et al*., 1998) because woody litter has high amount of sclerophyllous tissue which contains less amount of nutrient (Vitousek and Sanford, 1986).

The total amount of nutrient return to forest soil through litterfall is mentioned in table 5. N, P, K return through litterfall (kg $ha^{-1}y^{-1}$) was higher in TSF than HSF due to higher amount of litterfall. Along with, it also depends upon the nutrient

Table 4: Concentration (% ± SE) of nutrients in litterfall in Tarai Sal forest and Hill Sal forest

Forests/Components	Nutrients		
	N	**P**	**K**
Tarai Sal forest			
Leaf litter	0.93±0.023	0.086±0.001	0.41±0.01
Non leaf litter	0.57±0.024	0.057±0.002	0.30±0.02
Hill Sal forest			
Leaf litter	0.85±0.023	0.077±0.001	0.34±0.01
Non leaf litter	0.53±0.025	0.046±0.002	0.24±0.02

Table 5: Amount of nutrient return (kg ha^{-1} y^{-1} ± SE) through litterfall in Tarai Sal forest and Hill Sal forest

Forests/Components	Nutrients		
	N	**P**	**K**
Tarai Sal forest			
Leaf litter	57.28±2.15	5.29±0.09	25.25±0.7
Non leaf litter	15.16±0.63	1.51±0.03	7.98±0.38
Total	72.44±1.22	6.80±0.11	33.23±1.09
Hill Sal forest			
Leaf litter	42.81±0.28	3.85±0.04	17.03±0.72
Non leaf litter	11.50±0.52	0.99±0.07	5.20±0.37
Total	54.31±0.92	4.84±0.04	22.23±1.1

concentration of litter of tree species involved (Yang *et al*., 2005). Generally, montane forest leaves have lower nutrient concentration than those of fertile lowland forest (Vitousek and Sanford, 1986).

The nutrient contribution to the forest floor through the litterfall was comparable to Wanmulin Nature Reserve, China (Yang *et al*., 2005), forest of central Himalaya, India (Garkoti and Singh, 1995) and Plateau Sal forest, Nepal (Mandal, 1999). However, in Sal forest and mixed Sal forest of Bidhyan plateau, India (Sharma *et al*., 1990a) and in deciduous forest, India (Singh, 1968) the nutrient return from litterfall was relatively lower than the present study.

Litterfall is only the above ground source of soil organic matter which enriches the soil with nutrients essential for forest production. Removal or reduction of litter from forest floor can directly reduce the soil nutrients which ultimately affect the forest productivity. Hence, litter stands as an essential factor for better forest management.

Conclusion

It is concluded that litter production is influenced by the phenology of dominant tree species, variation in altitude and seasons, due to which low land Tarai Sal forest showed greater litter production and nutrient return to the soil. As TSF is rich in litter production and nutrient input in soil, it may have high production potential. Further, to manage the soil fertility, litter should remain undisturbed on the forest floor to regulate the nutrient cycling process. As the litter and litter mediated soil nutrients are essential for biomass production, it serves as a pronounced factor for the forest management.

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Distribution pattern of tree species from tropical to temperate regions in Makawanpur district, central Nepal

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Tree species are the dominant component of forest ecosystems which influence most structural and functional attributes of these ecosystems. This study aims to document distribution pattern of forest types and their composition from tropical region at Hetauda (550 m asl) to temperate region above Simbhangyang (2500 m asl) of Makawanpur district, central Nepal. The carbon stock in the living biomass of tree species was estimated using an allometric equation while the biodiversity index was calculated using Shannon-Wiener Biodiversity index. A total of 62 species of trees belonging to 51 genera was recorded. *Shorea* forest was dominant in lower elevation while *Quercus* forest, *Alnus-Rhododendron*, *Quercus-Lyonia* and *Quercus-Symplocos* forests at higher elevation. Similarly, *Castanopsis tribuloides* has the widest distribution range (570 m to 2240 m asl) followed by *Shorea robusta, Lagerstroemia parviflora*, *Trichilia connaroides, Syzigium jambos*, *Castanopsis indica*, *Schima wallichii* etc. The highest number of tree species was recorded at 550 m elevation. Estimated carbon stocks were ranged from 0.85 — 53.37 t/ha with the mean value 24.98 t/ha. The values of Shannon-Wiener Biodiversity index ranged from 1.23— 2.78. There was positive relationship between carbon stock and biodiversity index (R^2 = 0.40, p = 0.03). People have been practicing community forest management to support sustainability of harvesting in the study area.

Keywords: Allometric equation, biodiversity index, Daman, forest, Hetauda, species

Vegetation is the reflection of physiographic and climatic condition of an area. Nepal is a small country in terms of area, though it is rich in floristic composition. Being a mountainous country, altitudinal gradient is quite common feature of physiography which ultimately creates microclimatic condition that supports vegetation diversity. Floristic or inventory is the systematic enumeration and documentation of all plant species in a given geographic region and ideally provides keys, description and often illustration (Naik, 1998; Simpson, 2006). Exploration is the most important step of systematic study. In montane Nepal, altitude and aspect are the paramount importance in determining the type of forest found at particular place (Stainton, 1972).

Altitude, one of the major factors determining the climatic condition, affects directly the distribution of species of an area. Along with the increasing altitudinal gradient, the temperature and rainfall differ markedly so the species should adapt to the particular condition to sustain their life. However, majority of the species cannot adapt the major change in climatic conditions and become restricted to a limited elevation.

Forests being standing stores of sequestered atmospheric carbon can serve as valuable carbon pool. It is thus, the global communities become progressively more concerned with forest ecosystem as a tool to mitigate the impacts of climate change. This study focused on the distribution pattern of forest types and their composition along altitudinal gradient.

Materials and methods

Study area

This research work was carried out from Hetauda to Simbhangyang of Makawanpur district. All

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together 12 spots were fixed at different altitude (550 m to 2500 m) and forest types from Hetauda to Simbhangyang to cover maximum tree species as far as possible. The study area comprises tropical, subtropical and temperate climatic zones (DDC, 2015). Tropical zone comprises Sal and riverine forests at southern lower belts where *Shorea robusta*, *Terminalia chebula*, *Terminalia bellirica*, *Adina cordifolia*, *Acacia catechu*, *Dalbergia sissoo*, *Bombax ceiba* etc. flourish very well. Subtropical region consists of mainly *Schima*-*Castanopsis*, Chir pine and Alder forests comprising *Schima wallichii*, *Castanopsis indica*, *Castanopsi striduloides*, *Pinus roxburghii* as dominating species. Similarly, *Rhododendron arboreum*, *Myrica esculenta*, *Lyonia ovalifolia*, *Quercus lanata* as dominating species in the temperate forests. Sample plots of the study area is given in figure 1.

Fig. 1: Dots representing the sample plots of study area

Sampling design

A stratified random sampling method was used for locating the sample plots. The forest types were considered as strata. Altogether, 12 spots were fixed at different altitude (550 m to 2500 m) and forest types from Hetauda to Simbhangyang to cover maximum tree species as far as possible. At each spot, a square quadrate of 20m×20m was set up. Then, each sample plot was characterized by altitude, slope, aspect, crown canopy cover (%) and geographic location.

Data collection

Diameter at breast height (DBH) of tree standing at least a 1.3 m, and the height of individual trees of $\leq$ 5 cm DBH were measured. Species and their distribution were identified using relevant literature like Hara *et al*. (1978, 1979, 1982), Malla *et al*. (1986), Pande (1967), Press *et al*. (2000), Stainton (1988), Suwal (1969) while a few specimens were also confirmed by tallying with specimens deposited at KATH.

Data analysis

Distribution pattern of forest types and tree species along altitudinal gradient was analyzed using Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980). Since the mean annual precipitation of the study area is 2206 mm, the carbon stock in the living biomass of tree species was estimated using an allometric model for 'moist forest' (annual precipitation 1500—3500 mm) developed by Chave *et al.* (2005) while the biodiversity index was calculated using Shannon-Wiener biodiversity index as -

Allometric equation -

The aboveground biomass (kg) of a tree =

$$0.0509 \times \boldsymbol{\rho D}^2 H$$

Where, ρ is wood density (g cm^{-3}), H is height of tree (m), D is diameter of tree at breast height (cm) as proposed in forest carbon stock measurement guidelines (Subedi *et al.*, 2010). For dry wood density, the global database was used (Zanne *et al.*, 2009). The biomass stock (kg/m^2) of each sampling plot was obtained by dividing the sum of all the individual biomass by the area of sampling plot (400 m^2) and converted to tonnes per hectare. Later, biomass value was converted into carbon stock by multiplying with carbon fraction of 0.47 (IPCC, 2006).

Total biomass = Above ground biomass × 1.15

Carbon stock = Total biomass × 0.47

Shannon-Wiener biodiversity index-

$H' = -\Sigma pi \ln pi$

Where, H' is the diversity index, pi is the proportion of i^{th} species individuals to total species individuals, and ln is natural logarithm.

Results and discussion

Sixty two (62) tree species belonging to fifty one(51) genera was recorded. Among them, *Albizia*, *Quercus* and *Terminalia* were the largest genera with three species each followed by *Castanopsis*, *Pinus*, *Premna*, *Rhus* and *Vibernum* with two species each while remaining genera were monotypic ones (Fig. 2).

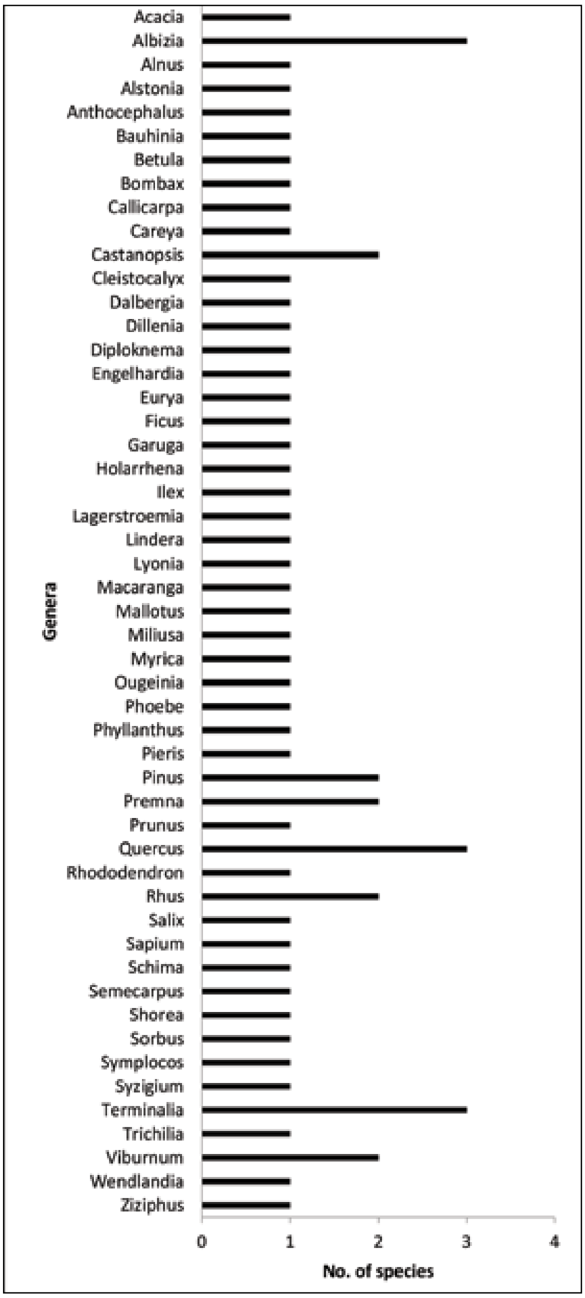

Fig. 2. Number of species per genera

Distribution pattern of forest along altitudinal gradient

The DCA axis I and II represent elevation and forest type, respectively. Species found towards the left and negative end of DCA axis I like *Albizia procrea, S. robusta, Trichilia connaroides* are highly abundant at lower elevation representing *Shorea* dominant forest (Fig. 3). The positive and right end of DCA axis I represents species abundant at high elevation. *Quercus* forest, *Alnus-Rhododendron*, *Quercus-Lyonia* and *Quercus-Symplocos* forest were dominant at higher elevation. Similarly, *Pinus* and *Alnus-Macaranga* were common at middle elevation (Fig. 3).

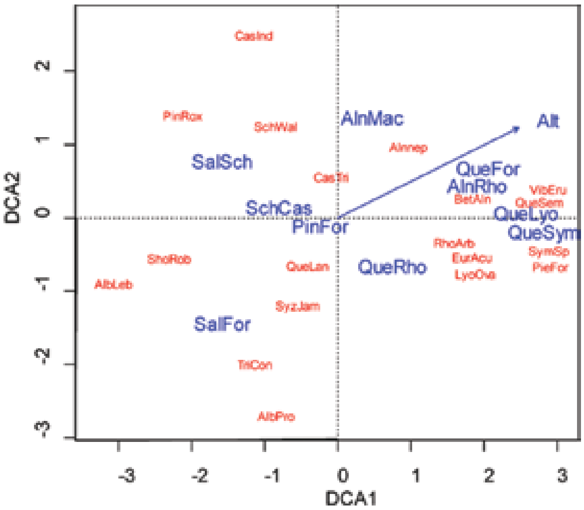

Fig. 3: DCA diagram showing environmental variation (elevation) represented by arrow and nominal variable (forest types) represented by bold words

Diversity index, carbon stock and altitude

The carbon stock in this study ranged from 0.85 — 53.37 t/ha with the mean value 24.98 t/ha. Similarly, Shannon's diversity index ranged from 1.23 — 2.78. The diversity index of species and carbon stock significantly decreased along altitudinal gradient (Fig. 4 and Fig. 5). However, there was no significant difference in density along elevational gradient.

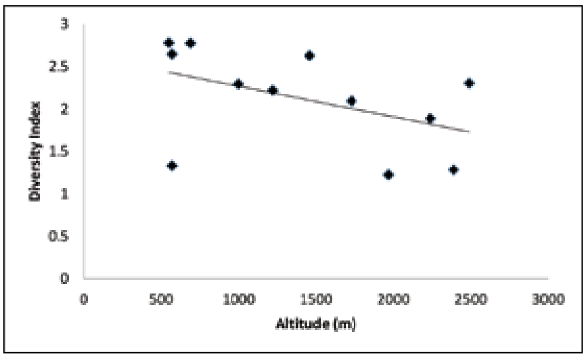

Fig. 4: Relationship between altitude and species diversity index

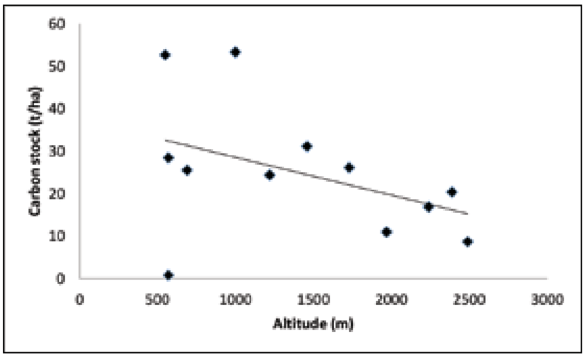

Fig 5: Relationship between altitude and carbon stock

Forest carbon stock and diversity index

The relationship between Shannon's diversity index and carbon stock in these plant communities was significant with a positive linear relationship (R^2 = 0.40, p = 0.03). Both carbon stock and Shannon-Weiner diversity index were gradually decreased with increase in elevation (Fig. 6).

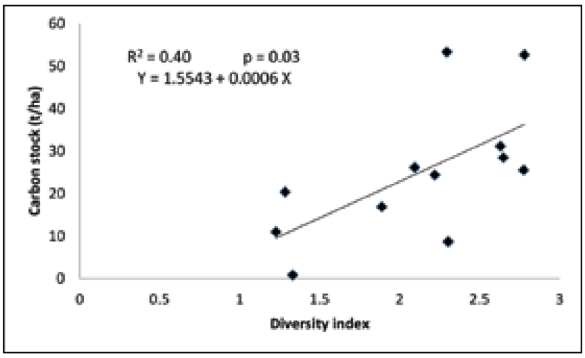

Fig. 6: Relationship between carbon stock and diversity index

Vegetation of an area is largely affected by various factors including temperature, rainfall, humidity, and soil characters, etc. which in turn get affected by altitude. The study area ranging altitudinal gradient from 550 — 2500 m provides a unique habitat for both flowering and non-flowering plants. In this study, *Albizia*, *Alstonia*, *Mallotus*, *Shorea*, *Garuga*, *Terminalia*, *Holarrhena,* etc. were the common species at lower elevation whereas *Acacia*, *Dalbergia*, *Bombax,* etc. were common along river side. Similarly, *Betula*, *Quercus*, *Pinus*, *Sorbus*, *Rhus*, *Macaranga*, *Prunus*, *Symplocos*, etc. represented the Mid-hill forests. Makawanpur district comprises 1068 species of flowering plants consisting of 210 tree species, 211 shrubs and remaining herbs (Chapagain *et al*., 2016). The study area represents a total number of 62 tree species belonging to 51 genera *i.e.* about one third of the total number of tree species of Makawanpur district. *Shorea* forest is dominant at lower elevation followed by *Pinus* and *Alnus-Macaranga* forest at the middle elevation and *Quercus*, *Alnus-Rhododendron* and *Quercus-Lyonia* forest at the higher elevation. Similarly, *C. tribuloids* had the widest distribution range (570 m to 2240 m asl) followed by *S. robusta*, *L. parviflora*, *T. connaroides*, *S. jambos*, *C. indica*, *S. wallichii*, *Wendlandia coriacea*, *L. ovalifolia* and *Alnus nepalensis.*

Though the standing biomass of tree species tended to concentrate in species of large trees, it seems that overall biomass values differed more due to species richness than species composition. A positive relation was found between Shannon's diversity index and carbon stock (R^2 = 0.40, p = 0.03). The lower belt was suitable for biodiversity to flourish well thus preserving much biomass and also carbon stock. The result showed that both biodiversity index and carbon stock were significantly higher in lower elevation and decreased along altitudinal gradient. The diversity-biomass relationship is affected by the environment (Guo and Berry, 1998). When environments are homogeneous, linear relationships are present, and when environments are heterogeneous, inverted U-type curvilinear relationships occur. Although hump-shaped or unimodal relationships between biomass and species diversity (Waide *et al*., 1999; Roy, 2001; Alhamad *et al*., 2010) have been frequently observed in mature vegetation, recent findings show positive relationship in establishing vegetation (Hooper *et al*., 2005; Spehn *et al*., 2005). This mechanism of changing relationship has been mainly discussed in terms of facilitation and competition i. e. when biomass is relatively low, diversity increases due to interspecific facilitation; whereas when biomass accumulates to a certain level, competition leads to lower diversity (Guo and Berry, 1998; Weiner and Thomas, 2001; Guo, 2007).

Conclusion

In the present study, the tropical forest represents the greatest value of both diversity index and carbon stock whereas these values get decreased along elevational gradient. This also indicates that species richness is positively related with biomass and carbon stock value thus conserving biodiversity is not only important in terms of conservation but also in mitigating the negative impacts of climate change issues. In other words, the present result has provided empirical support for the argument that increases in the biodiversity index could increase carbon stock if other anthropogenic and environmental factors are not limiting.

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Variation in structure and composition of two pine forests in Kailash Sacred Landscape, Nepal

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Chir pine (*Pinus roxburghii* Sarg.) and blue pine (*Pinus wallichiana* A.B. Jacks.) are two common species found in mid-hill forests of Nepal where households largely depend on forest resources for their livelihoods and subsistence. The management of such forests is supported by our understanding of the dynamics in forest structure and species composition and the relationship between different forest community characteristics. This study was designed to determine the variation in species composition and the relationship between various forest community characteristics in two pine forests of Kailash Sacred Landscape, Nepal.Quadrat sampling was applied to collect information on forest species, forest community structure, and disturbance factors.Data was statistically analyzed using IBM SPSS. There were a total of31 plant species under 28 genera and 20 families in the *P. roxburghii* forest, and 38 plant species under 37 genera and 19 families in the *P. wallichiana* forest. Mean DBH, height and canopy diameter of *P. roxburghii* was 23.98 cm, 12.77 m and 1.97 m, respectively, and that of *P. wallichiana* was 31.5 cm, 11.48 m and 2.79 m, respectively. The relationship between DBH and both height and crown diameter showed strong relationships in the two forest types.In both forests, DBH and height class distribution showed a hump-shaped (unimodal type) distribution with a greater proportion of medium-sized individuals that indicated disruptive forest regeneration. Fire and tree-cut were significant disturbance factors in *P. roxburghii* forest, while grazing and trampling were significant in *P. wallichiana* forest. The extent of these disturbance factors as determinants of regeneration and species recruitment is important to assess for effective forest management.

Key words: Community characteristics, disturbance, forest structure, *Pinus roxburghii, Pinus wallichiana*

The structure of a forest is determined by biotic and abiotic components (Behera *et al*., 2012; Mishra *et al*., 2013), along with human disturbance (Sanderson *et al*., 2002; Kareiva *et al*., 2007). Disturbance and biological processesare significant factors determining forest stand development (Franklin *et al*., 2002). Both forest structure and composition respond to environmental fluctuations and anthropogenic activities (Gairola *et al*., 2008). Moreover, stand structure, tree size and composition are key characteristics for maintaining ecological integrity and dynamics of forest ecosystems and their functions (Elourad *et al*., 1997;Kuuluvainen, 2002;Larsen *et al*., 2005; Merlin *et al*., 2014). These are also the basis for developing forest management and conservation strategies (Gutierrez and Huth, 2012). In mountain areas, forest structure and composition is regulated by slope orientation and elevation which both affect incoming solar radiation in an area (Gallardo-Cruz *et al*., 2009). Topographic variables, such as radiation, in turn affect species composition between slopes due to their influence on small-scale abiotic environmental variables (Ferrer-Castan and Vetaas, 2003; Paudel and Vetaas, 2014).

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Chir pine (*Pinus roxburghii* Sarg.) and blue pine (*Pinus wallichiana* A.B. Jacks.) are two pine species distributed mainly in the western Himalaya while also flourishing in Bhutan (Ohsawa *et al*., 1986). They are commercially important plant species in the Himalaya used for timber, turpentine and several medicinal and cultural purposes (Tiwari, 1994; Siddique *et al*., 2009). Several research studies have been conducted on these pine species from different parts of the Himalaya. A review of *P. roxburghii* was made by Kaushik *et al*. (2013) on ethnobotany and phytopharmacology. Dendrochronological study was carried out to determine the impact of climate change on growth of *P. wallichiana* (Bajwa *et al*., 2015). Similar work was conducted on *P. roxburghii* to understand stand age, structure, soil erosion, disturbance history and tree health (Speer *et al*., 2016). Composition, population structure and diversity of *P. wallichiana* in Garhwal Himalaya with special reference to altitude and aspect was studied by Bhandari (2003). Study on phytosociology of *P. roxburghii* was conducted by Siddique *et al*. (2009) in the lesser Himalaya and Hindukush range of Pakistan. Ghimire *et al*. (2010) carried out research on regeneration of *P. wallichiana* in the trans-Himalayan dry valley of north-central Nepal. Most research conducted in Nepal on these pine species are focused on allometric relationships for biomass prediction (Sharma and Pukkala, 1990), basal area growth model (Gyawali *et al*., 2015), dendrochronology (Schwab *et al.,* 2015) and carbon sequestration (Aryal, 2016).

In Nepal, chir pine and blue pine constitute 8.45% and 3.37%, respectively, of total forest area (DFRS, 2015). The two species are also the major constituents of forests in the midhills of Nepal (DFRS, 2015) where households largely depend on forest resources for their livelihoods and subsistence (Springate-Baginski *et al*., 2003). Long-term studies on forest socio-ecological systems are lacking in Nepal. This study was conducted in two pine-dominated community managed forests of Kailash Sacred Landscape (KSL) in Nepal to collect baseline information as part of a long-term socio-ecological study of forest ecosystems in the landscape. Knowledge on forest structure and composition is important for their management, but such studies are lacking in the landscape. Thus, the findings of this study will contribute to forest management while also providingbaseline data for long-term forest monitoring.The study addresses the following questions: 1) what are the variations in forest structure and species composition in chir pine and blue pine forests? and 2) what is the relationship between different community characteristics in the two pine forests ?

Materials and method

Study area

The study was carried out in KSL-Nepal (MFSC, 2016) (Fig. 1). The landscape, whichextendsbetween 29° 22' N to 30° 45'N latitude and 80° 15' E to 82° 10' E longitude, covers an area of 13,289 sq. km and comprises the districts of Baitadi, Bajhang, Darchula and Humla.Altitudesin KSL-Nepal range from 390 m to 7,132 m above sea level (masl). The climatic condition of the area is characterized by high rainfall and humidity, with average rainfall of 2,129 mm. Average maximum and minimum temperature is 18.6°C and 7.7°C, respectively. Forests occupy almost 30% of the total area of KSL-Nepal of which subtropical broadleaved forests (with *Shorea robusta*, *Terminalia alata*, and *Pinus roxburghii*) constitute 10% and uppermontane conifer forests (with *Cedrus deodara*, *Cupressus torulosa*, *Tsuga dumosa*, and *Pinus wallichiana*) constitute 3%.

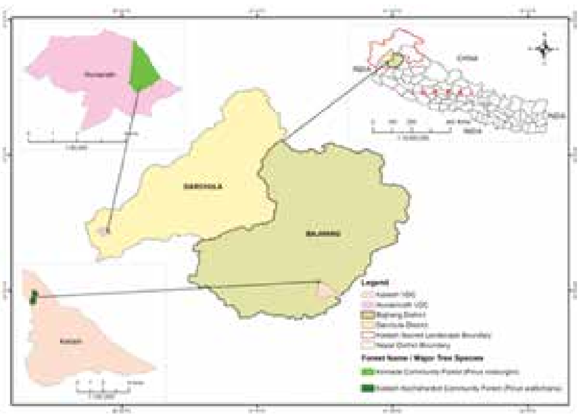

Fig. 1: Map of the study area.

The forest survey was conducted in two community managed forests in the landscape: Kirmadhe Sinnadi in Hunainath Village Development Committee (VDC) of Darchula district and Kailash Kachaharikot Mahila in Kailash VDC of Bajhang district. Kirmadhe

Sinnadi community forest (CF) covers an area of 50.76 hectares (ha). Altitudes in this CF range from 1808 to 1958 m asl and slopes between 5° to 21°with the forest oriented towards east and west. *P. roxburghii* is the dominant tree species while other tree species include *Quercus lanata*, *Rhododendron arboreum* and *Myrica esculenta.* Kailash Kachaharikot Mahila CF covers an area of 20 hectares. Altitudes range from 1800 to 2100 masl and slope between 20° to 35°with the forest oriented towards south and west. *P. wallichiana* is the dominant tree species in this CF.

Field methods

Field work was conducted between May and June 2016 to establish permanent forest monitoring plots in the two pine forests. The boundaries of both forests were delineated using a Global Positioning System (GPS) device - Garmin Oregon 650. The forest boundary was then transferred to Google Earth map where a 20m*25m grid was overlaid. Sample forest plots were then randomly selected and verified in the field. Based on the total size of the CFs, ten permanent plots were established in *P. roxburghii* forest and four in *P. wallichiana* forest. Each plot was further divided into 20 5m*5m subplots to collect data on plant life forms (Fig. 2). The location of each plot was recorded using a GPS device, and topographic variables including altitude, slope and aspect were recorded with an altimeter (Suunto). In each plot, grazing, trampling, cutting, lopping and fire were visually estimated as disturbance variables. They were recorded on a scale ranging from 0 (no visible sign of disturbance) to 3 (high disturbance). Ocular estimate of top canopy (tree crown), mid canopy (canopy of shrubs and saplings) and low canopy (canopy of herbs, forbs and seedlings) was made from the center of each subplot.

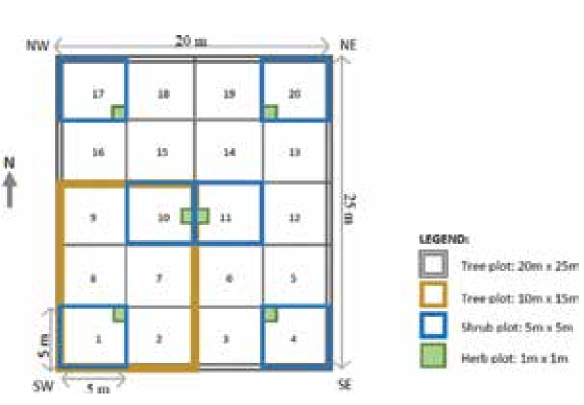

Fig: 2 Vegetation sampling design

Vegetation sampling

Based on diameter at breast height (DBH) and height (H) of the individual, plant species were classified in to three categories, *viz.* tree (>10 DBH), saplings (< 10 cm DBH and H >1.3 m) and seedlings (H<1.3 m) (Newton, 2007). Individual trees were recorded in the entire 20m*25m plot (hereby referred here as 'tree plot'). DBH of each individual tree was measured at 1.3 m height from the ground usingMillion diameter tape(YAMAYO) and its height with a Vertex IV (Haglof Sweden). Canopy of each individual tree was measured in eight directions from the center. Tree saplings were measured in a nested 10m*15 msubplot (sapling plot) within the tree plot. The number and percentage cover of shrubs were recorded in six 5m*5m subplots(shrub plot), four of which were fixed at the corners of the tree plot and two at the center. Similarly six 1m*1m subplots(herb plot) nested within the subplot were used to record herbaceous vegetation. The number of herb species and an ocular estimate of their percent cover was recorded. Most of the plant species were identified in the field withstandard flora (Stainton, 1997; Polunin and Stainton, 2000). Unidentified plant species were collected and later identified usingavailable literature (Sharma and Kachroo, 1983; Stainton, 1997; Polunin and Stainton, 2000) and by consulting herbarium specimens housed at Tribhuvan University Central Herbarium (TUCH) and National Herbarium and Plant Laboratory (KATH). Plant species nomenclature follows Press *et al.* (2000).

Statistical analysis

Spearmen's correlation was used to determine relationships between different characteristics of forest community and environmental variables. Linear regression analysis was performed to determine relationships between different forest community characteristics. The regression coefficients and equationswere obtained through a fitted line on the scattered plot, and F and p valueswere obtained through ANOVA. Before regression analysis,all disturbance variables (grazing, trampling, cut, harvesting and fire) were combined through dimension reduction process in Principle Component Analysis (PCA) to obtain a combined measure of disturbance. IBM SPSS was used for data analysis.

Table 1: Floristic composition in pine forests

Life form	Occurring in only		Common to both forests
	P. roxburghii **forest**	***P. wallichiana*** **forest**	
Trees	*Alnus nepalensis, Quercus lanata*	*Symplocos paniculata*, *Viburnum erubescens*	*Lyonia ovalifolia*, *Rhododendron arboreum*
Shrubs	*Hedysarum kumaonense*, *Rubus paniculatus*	*Cotoneaster frigidus*, *Cotoneaster microphyllus*, *Daphne papyracea*, *Indigofera heterantha*, *Inulacappa*, *Myrsine africana*, *Prinsepia utilis*, *Pyracantha crenulata*, *Smilax aspera*, *Spiraea bella* and *Viburnum cotinifolium*	*Berberis asiatica*, *Rubus ellipticus*
Herbs	*Anaphalis busua*, *Cirsium wallichii*, *Commelina benghalensis*, *Curculigo orchioides*, *Drosera peltata*, *Fimbristylis dichotoma*, *Hypericum japonicum*, *Reinwardtia indica*	*Bidens pilosa*, *Centella asiatica*, *Gaultheria nummularioides*, *Gnaphalium affine*, *Origanum vulgare*, *Potentilla sundaica*	*Anaphalis triplinervis*, *Carex filicina*, *Erigeron karvinskianus*, *Flemingia strobilifera*, *Fragaria indica*, *Galiu melegans*, *Gonostegia hirta*, *Imperata cylindrica*,, *Micromeria biflora*, *Oplismenus compositus*, *Oxalis corniculata*, *Taraxacum parvulum*, *Viola serpens*, *Ageratina adenophora*

Results and discussion

Floristic composition

There were 31 plant species belonging to 28 genera and 20 families in *P. roxburghii* forest, and 38 plant species belonging to 37 genera and 19 families in *P. wallichiana* forest. Based on life forms, 22 herbs, 4 shrubs and 5 trees were recorded in the *P. roxburghii* forest, and 19 herbs, 13 shrubs and 4 tree species were found in *P. wallichiana* forest. 14 herbs, 2 shrubs, and 2 trees were common to both forests while 8 herbs, 2 shrubs and 3 trees were found exclusively in *P. roxburghii* forest and 6 herbs, 11 shrubs and 3 trees exclusively in *P. wallichiana* forest (Table 1).

P. roxburghii is invasive in nature and can easily replace broadleaved species, ultimately leading to monoculture forest development (Bhandari, 2003). It has competitive superiority than other species in obtaining resources (Bargali, 1997). It is a light demanding and fire promoting species. Surface fire causes substantial loss of nitrogen, and this depletion on nitrogen is the major cause of monoculture development of pineforests (Singh *et al*., 1984). Phytosociological analysis showed that *P. roxburghii* was generally distributed in pure form (Siddiqui *et al.* 2009). Pine forests are affected by fires especially in the summer season resulting in deterioration of soil fertility and development of new species. Fire reduces total organic matter, phosphorus and potassium (Benerjee and Chand, 1981; Ghotz and Fischer, 1982). In comparison to *P. roxburghii*, *P. wallichiana* tends to share its habitat with other tree species (Bhandari, 2003) resulting in higher species richness in this study.

Forest structure

The DBH and height class distribution of *P. roxburghii* population is presented in Fig.3 and of *P. wallichiana*in Fig. 4. In both forests,DBH and height class distribution showed hump-shaped (unimodal type) distribution with greater proportion of medium-sized individuals. There was a gradual increase in the proportion of individuals of DBH class up to >20-<30 cm for *P. roxburghii* and >30-<40 for *P. wallichiana*, and height class upto>10-<15 mfor *P. roxburghii* and >15-<20 m for *P. wallichiana* after which height class gradually decreased.

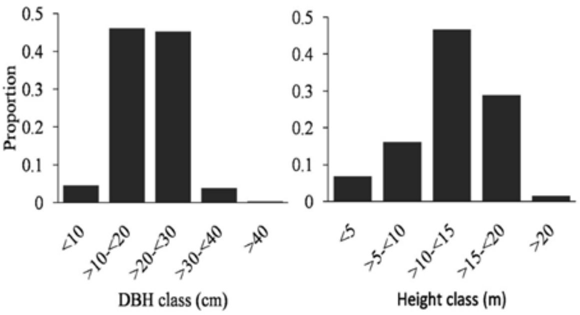

Fig. 3 DBH and height class distribution of *P. roxburghii*

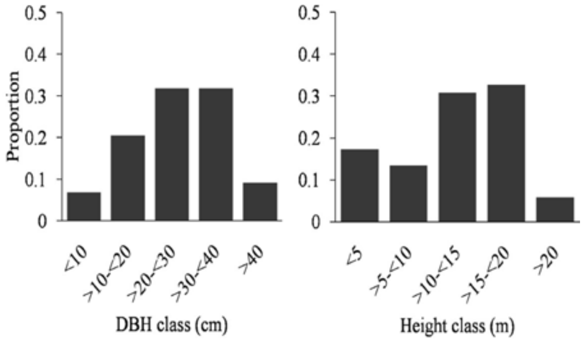

Fig. 4 DBH and height class distribution of *P. wallichiana*

The size distribution of trees is an important indicator for population dynamics and for forest management (Kohira and Ninomiya, 2003; White *et al*., 2007). This study showed that there were fewer juveniles as compared to adults in the two forests indicating disruptive regeneration probably due to disturbance (Condit *et al*., 1998; George *et al*., 2005; Deb and Sundriyal, 2008). A study on *P. roxburghii* in Bhutan showed unimodal distribution resulting from anthropogenic and natural disturbances (Wangda and Ohsawa, 2006). Both forests in KSL-Nepal are used by local communities, especially for extraction of timber, and hence the preference for large-sized trees. While felling such trees, the resulting disturbance on seedlings and saplings could possibly affect their regeneration.

Relationship between forest community characteristics

The forest community characteristics of *P. roxburghii* and *P. wallichiana* are presented in Table 2. Density of pine was high in both forests. Mean DBH, height and canopy diameter of *P. roxburghii* was 23.98 cm, 12.77 m and 1.97 m, respectively, and that of *P. wallichiana* was 31.5 cm, 11.48 m and 2.79 m, respectively. The mean top and mid canopy cover was higher in *P. wallichiana* forest than in *P. roxburghii* forest, but low canopy cover was highest in the latter forest.

Table 2: Community characteristics of *P. roxburghii* and *P. wallichiana* forest

Variables Mean (SE)		*P. roxburghii*	*P. wallichiana*
		Mean (SE)	
Number of tree species		1.60(0.31)	2.00 (0.45)
Density of Pine (number/**ha**)		168.5 (7.15)	65.00 (3.73)
Mean DBH (cm)		23.99 (1.78)	31.02 (4.70)
Mean height (m)		12.77 (0.83)	11.49 (1.02)
Mean canopy diameter (m)		1.97 (0.19)	2.80 (0.15)
Canopy (%)	Top	27.03 (3.36)	32.75 (3.31)
	Mid	4.25 (0.60)	16.50 (1.96)
	Low	14.59 (1.18)	12.00 (2.61)

The dimension reduction process in PCA resulted in two PCA factors explaining 56.5% of variance: PCA factor 1 (31.32% variance) explained grazing (0.841) and trampling (0.858) as main associated variables; and PCA factor 2 (25.23% variance) explained tree cut (0.807) and fire (0.734) as main associated variables in *P. roxburghii* forest. In *P. wallichiana* forest, two PCA factors were obtained explaining 55.2% of variance: PCA factor 1 (35.25% variance) explained grazing (0.801) and trampling (0.851) as main associated variables, and PCA factor 2 (19.95% variance) explained tree cut (0.782), harvesting (0.517) and fire (0.539) as main associated variables.

The density of *P. roxburghii* was negatively correlated with mean DBH ($r = -0.872$, $p = 0.01$) and canopy diameter ($r = -0.770$, $p = 0.01$) and positively with disturbance factor 2, *i.e* fire and cut ($r = 0.792$, $p = 0.01$). Since the local villagers had extracted large sized trees for timber and fire allows regeneration of pine seedlings (Paucas *et al*., 2004), large sized tree with larger DBH were absent in the forest. *P. roxburghii* can tolerate more stress and potentially colonize disturbed and moisture-deficient areas (Singh and Singh, 1992; Ryan and Yoder, 1997). Fire helped liberate seeds from cones allowing their regeneration and monospecific stand development in *Pinus halepensis* (Pausas *et al.,* 2004; Moya *et al*., 2007). Tang *et al*. (2013) reported that the natural recovery of *Pinus yunnanensis* was more efficient after fire contributing to the density of pine in central Yunan, China. The mean DBH was positively correlated with mean canopy diameter (r = 0.841, p = 0.01). The mean crown radius was the function of stem size, stand density and site productivity and the canopy radius increased linearly with DBH (Avsar and Ayyildiz, 2005; Attocchi and Skovsgaard, 2015).

Strong negative correlation was found with canopy diameter and number of tree species (r=0.987, p = 0.05) in *P. wallichiana* forest. Crown morphology has important implications to compete with other species in a community (Messier, 1996; Messier *et al*., 1999). High tree canopy cover reduces the amount of solar radiation to the ground while facilitating more litter deposition which is not a favorable condition for seedling establishment (Spanos *et al*., 2001).

DBH-height relationship

A significant linear relationship (p<0.001) was found between DBH and height (R^2 = 0.571 for *P. roxburghii* and 0.551 for *P. wallichiana*) (Fig. 5 (a) and (b)). The strength in relationship between DBH and height of the two pine forests was not significantly different. The height–diameter relationship of trees are stand specific, site specific, and time specific and also differ within a site due to competition among trees (Trincado *et al*., 2007; Pretzsch, 2009; Schmidt *et al*., 2011). Tree diameter has a significant correlation with the height and age of the forest stand and thereby directly affects sustainable volume production (Khan *et al*., 2016). This correlation depends on the growing environment and stand conditions (Calama and Montero, 2004; Sharma and Zhang, 2004).

DBH-crown diameter relationship

Measurement of crown diameter is usually not carried out in forest inventory but is important to measure some competitive measures and to determine canopy cover (Biging *et al*., 1995; Gill *et al*., 2000; Popescu *et al*., 2003). The R^2 value obtained from regression between DBH and crown diameter in this study was 0.572 in *P. roxburghii* forest and 0.422 in *P. wallichiana* forest (Fig. 5 and 6). Gill *et al*. (2000) developed models for different coniferous trees of California and obtained R^2 values between 0.2691 and 0.6077 where DBH predicted most of the model. Incorporation of crown area into models improved accuracy of the predictions (Nakai *et al*., 2010; Gonzalez-Benecke *et al*., 2014).

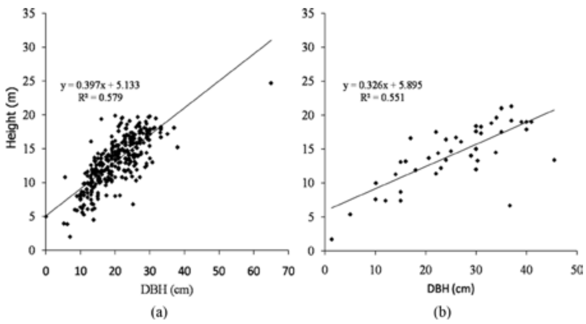

Fig 5 Regression between DBH and height of (a) *P. roxburghii* (b)*P. wallichiana*

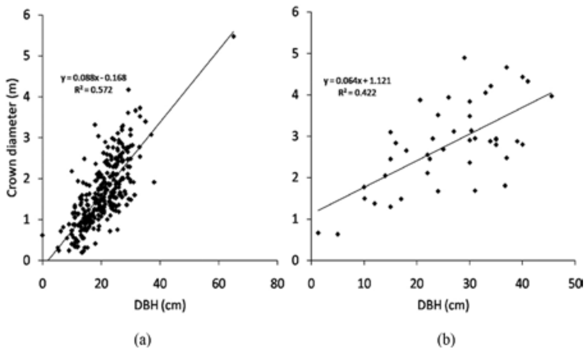

Fig 6 Regression between height and crown diameter of (a) *P. roxburghii and (b) P. wallichiana*

Conclusion

Pinus roxburghii and *Pinus wallichiana* are important needleleaved species occurring in subtropical broadleaved and upper montane conifer forests in KSL-Nepal. This study presents the forest structure and species composition of two pine forests selected for conducting long term socio-ecological research in the landscape. Both forests were dominated by the respective tree species, with mean number of tree species being 1.60 (± 0.31) in *P. roxburghii* forests and 2.00 (± 0.45) in *P. wallichiana* forests. Tree density averaged 168.5 (± 7.15) and 65.0 (± 3.73) stems per ha. in *P. roxburghii* and *P. wallichiana* forests, respectively. Size distribution of trees displayed a unimodal type with greater proportion of medium-sized individuals. The structure of both forests indicates that they are heavily disturbed. Fire and tree cut were significant disturbance factors in *P. roxburghii* forest, while grazing and trampling were significant in *P. wallichiana* forest. The extent of these disturbance factors as determinants of regeneration and species recruitment is important to assess for effective forest management.

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Locally identified criteria, indicators and verifiers for evaluating sustainable community based forestry: a case from Nepal

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Community based forestry is seen in many countries as a way to enhance sustainable forest management through close involvement of local people. This paper aims to develop understanding of local perspectives on criteria, indicators and verifiers for evaluating sustainable community based forest management practices. This study includes ten different forest user groups ranging from full autonomy to semi-autonomy in making decisions regarding forest management practices covering three districts from three physiographic (mid-hill, inner-tarai and tarai) regions of Nepal. A village to village approach was used to acquire the perspectives from male, female and different castes. The findings show that local people identified four criteria, 26 indicators and 60 verifiers for evaluating sustainable community based forest management practices. Three locally identified criteria were found to be identical with the institutional top-down criteria. The paper concludes that understanding local knowledge, local practice and associated institutions are important to manage forest resources in a sustainable manner. There is also a need to have continuous collaborative works between forest professionals and local people to enhance sustainable forest management.

Key words: Community based forestry, criteria and indicator, evaluation, local people, sustainable forest management

The paper contributes in developing an understanding of local perspectives on criteria, indicators and verifiers for evaluating sustainable community based forestry. It illustrates the people's perspectives from three different community based forest management practices ranging from full autonomy to semi-autonomy in making the decisions regarding forest management practices. This paper defines semi-autonomy and full autonomy as an executive body composed of local people with and without representation from the government officials, respectively. We assume that people make the decisions independently regarding forest management practices if there is no representation from the government official in the executive body. It is likely that representation from the government in the executive body may have some kind of influence in making the decisions, particularly in managing forest resource with an interest of the government officials rather than people's interests. Local people considered government officials as an expert in the respective areas and often trust and accept their views accordingly (Kumar, 2000; Pokharel, 2000).

Managing forest resources in a sustainable way is a challenge in a country where people are dependent on forest resources for their livelihoods. People use forests for a number of things such as grazing for livestock, fuel wood for cooking, timber for construction of houses and agricultural tools, and NTFP collection, processing and sale. Munang *et al.* (2011) reported that about 410 million people are highly dependent on forests for subsistence needs and income. They also estimated that 1.6 billion people indirectly depend on forest goods and services for their livelihoods. Community based forestry is seen in many countries as a way to enhance sustainable forest management through close involvement of local people. Principally, community based forestry invites local people to join their hands in the management of forest resources and encourage them to involve in different levels of management. However, inviting

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people to involve in different levels of management varies from one place to another depending on the context. Around one-quarter of forests in developing countries is under the community based forestry (White and Martin, 2002 cited by Sikor, 2006; Shyamsundar and Ghate, 2011).

The concept of sustainable development was adopted at the United Nations Conference on Environment and Development (UNCED) in 1992 where sustainable forest management has been considered as an integral part of sustainable development (Bebarta, 2004). Sustainable forest management is the aim of Nepal's community forestry programme (Acharya, 2002) and adopted it as one of the models of community based forestry. Community forestry is a pioneer and well-established management form of community based forestry in Nepal (Pokharel, 2009) which is seen as a way to enhance sustainable forest management through direct involvement of local people. Evidences show that deforested and degraded forest lands under the community forestry have been reforested and improved in quality. Community forestry in Nepal has improved biophysical environment / tree generations (Gautam *et al*., 2002; Yadav *et al*., 2003; Gautam *et al*., 2004; Nagendra *et al*., 2008; Gautam, 2009; Tachibana and Adhikari, 2009).

Sustainability of community based forestry can be understood as the condition of utilization, development, and conservation of forest resources under which the social, economic, ecological, cultural and spiritual needs of present and future generation of the local people are maintained and enhanced. There is an increasing trend of transferring management responsibility of forests from the government to local community. Transferring the management responsibility to local people is seen as one way of making the forests sustainable. However, simply by transferring management responsibility to local people alone cannot guarantee the sustainability of community based forestry. A self-monitoring tool is essential that allows local people to track the progress of forest management towards the goal of sustainability. Criteria and indicators are being promoted internationally as a basis of user group self-monitoring (Louisa and Edwards, 1995). Although some studies (such as Pokharel, 2005; Pokharel and Larsen, 2007, 2009; Pokharel and Suvedi, 2007; Pokharel and Tiwari, 2013; Pokharel *et al*., 2015) have focused on local knowledge for developing criteria and indicators, little attempts have been made to make the evaluation system transparent. There is a trend of manipulating things by the people in power in favour of *afno manche* (relatives or friends) in Nepal (Pokharel and Larsen 2009) which makes transparency important to motivate forest users and to encourage people to join in the work being done. The paper identifies criteria, indicators, and verifiers for evaluating sustainable forest management practices as perceived by local people.

Materials and methods

Study area and data collection

This study covered ten different forest user groups from three community based forest management (CBFM) practices (community forestry, buffer zone community forestry and collaborative forest management) of three different districts (Tanahu, Chitwan and Bara) representing mid-hills, inner-tarai and tarai regions of Nepal (Fig. 1).

Fig. 1: Map of the study areas

Three different districts from three different physiographic regions (one district from each region) were chosen as study sites to observe the difference in perceptions and management practices. Among three districts, Tanahu represents mid-hills, Chitwan lies in inner-tarai region, and Bara represents tarai. Tarai is characterized as flat area which stretches from east to west of Nepal. Two forest user groups from community forestry were chosen from each district and two forest user groups each from buffer zone community forestry and collaborative forest management were chosen from Chitwan and Bara districts, respectively. Forest user groups from different forest management models were selected by using three key criteria: i) user group managing natural *Shorea robusta* (sal), ii) user groups have less intra group conflicts, and iii) user groups are interested to share their ideas. *S. robusta* is a major timber species that generates high income and is considered one of the important aspects for sustainability of community based forestry (Pokharel *et al*., 2015). A series of discussions were held with District Forest Offices of the respective districts on user group selection criteria.

Two community forest user groups (Sapankot Odare and Kyamin Hariyali) from Tanahu district, four forest user groups (two buffer zone community forest user groups – Bandevi Barandabhar, and Chitrasen and two community forest user groups – Dhudhakoshi and Jaldevi) from Chitwan district, and four forest user groups (two collaborative forest management user groups – Balkhoriya and Sahajnath and two community forest user groups – Pragatishil and Thanimai) from Bara district were selected as study sites.

A village to village approach suggested by Pokharel and Helle in 2009 was used for gathering information, particularly to cross check the information and acquire the perspectives from male, female and different castes. Ten meetings were conducted with ten different forest user groups (one meeting for each forest user group) individually. One of the meetings held with Thanimai Community Forest User Group (CFUG) is given in figure 2.

Fig. 2: Meeting with Thanimai CFUG

The participants for the meeting were selected with the assistance of the chair or secretary of the executive committee. The duration of the meeting was from 2 to 4 hours. The meeting venue was office buildings mostly except in one forest user group (Kyamun Hariyali) as people from Kyamun Hariyali felt comfortable to hold meeting in an open place rather than in office building.

We directly approached forest users for small groups meetings since the authors were familiar with the local situation and the CFUGs. We first contacted a random individual in the field and requested him or her to take us to chair/secretary or invite a few more individuals for small group meeting including chair or secretary. The average group size of the meeting was 13.77 (±7.21). During the meeting, they were asked to identify criteria, indicators and verifiers for a sustainable community based forest management. The criteria and indicators were listed by researcher on a flip chart until no criteria and indicators were suggested. After finishing the list of criteria and indicators, the researcher read out the list aloud and the participants discussed the relevance among themselves. The researcher encouraged especially women to voice their opinion during the discussions. An effort was made to include women for the meeting.

Results and discussion

Size of forest user groups and participants' characteristics

The size of households of ten forest user groups ranged from 210 to 27,121. They had managed forests in a range of 84 to 2,058 hectares of natural forests along with small areas of plantation. Among the participants in the meeting, one-fifth (20%) was female and the remaining (80%) were male. The average age of the participants was 44.09 years (±11.59 years) and the average age of female and male found to be 37.68 years and 45.71 years, respectively. Getting involved women and poor in the meeting was challenging. Generally, women and poor feel comfortable relatively to attend a public meeting if they are invited by their relatives, neighbours or local leaders rather than an outsider. Although the researcher made the effort to include women for the meeting the result was not satisfactory. In few cases, women's presence in the meeting was nil. This may be due to their busy schedule as it was the season for rice harvesting.

Criteria, indicators and verifiers

The Montreal Process (1995) defines a criterion as a category of conditions or processes by which sustainable forest management may be assessed. The process also defines indicator as a measurement of an aspect of the criterion. Prabhu *et al.* (1999) defines an indicator as any variable or component of the forest ecosystem or management system used to infer the status of a particular criterion. Indicators are often used to measure changes, particularly when changes cannot be measured directly (WHO, 1981). For this study, we defined criterion as an aspect of forest management that is considered important by which sustainable forest management may be assessed. Similarly, we defined an indicator as a quantitative, qualitative or descriptive attributes that indicates direction of change in a criterion when measured or monitored periodically. And verifiers are the data or specific information collected for assessing an indicator. Local people considered four aspects that are considered important in managing their forests and identified them as criteria which obviously helped them to assess or judge the sustainable forest management practices. They are i) extent of resources, ii) economic and social benefits, iii) forest management practices, and iv) institutional framework and governance. Similarly, ITTO (2005) stated that a total of seven criteria [(1) extent and condition of forests (2) biological diversity (3) forest ecosystems health (4) forest productions (5) soil and water protection (6) socio-economic benefits and needs and(7) legal, policy and institutional framework] were agreed globally for sustainable forest management which may be seen as institutional top-down criteria. These criteria are related to environmental, socio-economic, institutional, and social aspects.

The locally identified criteria are related to environmental, socio-economic, social and institutional aspects. The identified three criteria (number 1, 2 and 4) found to be identical with other studies (FAO, 1999a, 1999b; UNDP, 1999; ITTO, 2005; CCFM, 2006; Pokharel and Larsen, 2007; Jalilova *et al.*, 2012). However, they are presented in a different way. The criteria number 3 is similar with the findings of Pokharel and Larsen (2007) and also matches with the criterion number 4 of institutional top-down criteria (such as UNDP, 1999; ITTO, 2005) as both focus on social aspect. However, it is presented differently in the institutional top-down criteria as forest production. Maintaining forest production requires management so it can be grouped as same i.e., forest management practices. Local people considered forest management practices as one of the criteria for sustainable forest management as it is the only way of legally fulfilling basic forestry needs of rural people in a community managed forests and also improving the forest health. Similarly, local people identified the total of 26 indicators and 60 verifiers for evaluating sustainable community based forest management practices. They identified six and eight indicators and 13 and 18 verifiers under the first and second criterion, respectively (Table 1). Similarly, they identified seven indicators and 11 verifiers for the third criterion. For the fourth criterion five indicators and 18 verifiers were generated locally (Table 1). While discussing, they related it with their day-to-day and identified criteria, indicators and verifiers.

People identified forest condition, forest growth and harvest, greenery, forest ground coverage, changed forest area over time, and wildlife in forest as indicators for the first criterion i.e., extent of forest resources. Status of tree species, regeneration status, trees with different classes, canopy cover, good shape trees, forest area with destructive weeds were identified as verifiers to determine forest condition. The findings of this study, particularly, verifiers to determine the forest condition are similar with other studies

Table 1 Locally identified criteria, indicators and verifies for a sustainable CBFM

SN	Criteria	No. of indicators	No. of verifiers
1	Extent of forest resources	6	13
2	Economic and social benefits	8	18
3	Forest management practices	7	11
4	Institutional framework and governance	5	18
Total	**4**	**26**	**60**

(Pokharel and Larsen, 2007; Pokharel and Suvedi, 2007). Status of valuable tree species is important for motivating people towards management as people may require less walk to find timber for construction of their houses and furniture and also facilitate to maintain diversity in the forest. Higher diversity of tree species is likely to maintain resource level in forests leading to sustainability. Higher species diversity is associated with their long term stability, allowing for niche diversification and low extinction rates (Stebbins, 1974). Frequency of seedlings and tree distribution per unit area is considered as a major indicator of stand structure. And stand structure with capacity of supplying diverse products in a sustainable basis is an indicator of sustainable management.

Destructive weeds and climber were increasingly seen in the forest and people perceived it as verifier to determine forest condition. Destructive weeds and climber are the threat to tree species and may displace them as people explained during the discussion and they are in an increasing trend in their forests which may pose threat to the sustainability as well. People were conscious about how much forest products especially timber is being harvested from forest and put it as an indicator to determine whether forest management practice is sustainable or not. Determining the sustainable forest management practice requires knowing how much timber is available and how much being harvested and replanted each year (CCFM, 2006). Forest land conversion into other land-use is one of the problems in Nepal and people identified it as an indicator for the extent of forest resources. Higher the conversion of forest land into other land use is likely to make less availability of forest resources. Forest land conversion is driven primarily by the expansion of agriculture and urbanization. The construction of permanent roads has also converted the area of forest land into other land-use in Nepal. The number of verifiers varied from one to six for each single indicator under the extent of forest resources (Annex 1).

People feel that socio-economic issues are important and need to be addressed to motivate rural people towards forest management and its sustainability as well. Community based forestry is essential about sustainable management of both people and forest resources which may lead resource degradation if it is not managed properly. Social sustainable is important to consider for sustainable management in community based forestry. The management system in a common property like forest is likely to break down if it is not socially sustainable resulting in environmental degradation (Arnold and Steward, 1998).The distribution of costs and benefits are equally important to make people adhere to rules and regulations. If costs and benefits are equally distributed among the members, adherence to regulation is more likely (Singh, 2002). Awareness of people towards the importance of forestry, participation of people in forestry works, access to benefits, distribution of benefits, motivational works towards forestry, employment through forestry, generating common funds through forestry, and mobilization of forestry funds are identified as indicators to decide economic and social benefits. Benefit sharing is considered as an important indicator for the sustainable management of community based forestry (Hobley, 1996; Pietrowicz, 2000; James and Karan, 1997). For each indicator, the number of verifiers varies from one to four under the criteria of economic and social benefits (Annex 1).

Local people perceived forest management practices as an important activity that allows extraction of forests products legally from the forest and considered it as one criterion for sustainable forest management. Pokharel and Tiwari (2013) argue that forest management is an essential activity that not only makes the forest healthy and productive but also allows local people to extract forest products legally by ensuring their participation in the management practices being applied. Operational plan at community forestry is a required document which explains the ways of managing the forests focusing to different activities such as real forest condition, forest protection systems, and forest product extraction and distribution. Mismatch between the real forest conditions and adopted management plan is likely to lead ineffective management practices. Studies (such as Pietrowicz, 2000; Hobley, 1996) argue that most of the failure cases in resource management are because of mismatch between the real condition of the resource and adopted management plan. Local people identified silvicultural operations, plantation activity, incidence of forest fires, block divisions, wetland in forest, grassland in forest, and recreation area in forest as indicators to determine forest management practices. Although forest fire is considered as essential element of forest management, it is often seen by local people as destructive in Nepal's community based forestry and identified forest fire as indicator to determine forest management practices. Forest fires are an essential element of forest renewal as they help control insect and disease damage and eliminate litter that has accumulated on forest floors (CCFM, 2006). Some species of trees actually require the intense heat generated by forest fires to release their seeds (*ibid)*.

Local people see institutional aspect as important criteria for evaluating sustainable community based forestry. An institutional framework and governance is essential to put the policy into practices and also sharing the benefits. A favourable community based forest management policy is likely to attract people in the management. During the discussion, local people reflected that a favourable government policy made them to get involved in community based forestry. They realized the necessity of local institution in order to manage forest resources for a long run and also emphasized the need of good governance. Good governance is considered necessary in realizing the full potential of community forestry in contributing towards the goal of poverty reduction (Pokharel and Tiwari, 2013a). Local people think that governance is equally important for effective forest management and also giving the continuity to the management for long run by involving local people. Local people identified policy, leadership, composition of executive body, transparency and office management as indicators for tracking the progress on institutional aspect of forest management towards the goal of sustainability. Organizational leadership behaviors have a direct influence on actions in the work environment that enable change (Drucker, 1999; Gilley, 2005; Howkins, 2001). The verifiers ranged from two to six for different indicators under institutional framework and governance (Annex 1).

Wetland, grassland, recreation area in forest, motivational works towards forestry and office management are new indicators suggested by this study for a sustainable CBFM. Wetland and grassland indicators were reported only by forest user groups from buffer zone community forestry. Local people think wetland is important for wildlife. Loss of wetland in a forest may indicate loss of habitat, food, and shelter for wildlife. Wetland is important as it provides essential habitat to a myriad of wildlife species including migratory birds (CCFM, 2006). The report also states that forest wetlands are major sources of recharge for ground water and also for regulating flows of surface water.

Conclusions

Understanding local knowledge, practice, and associated institutions are important to manage forest resources in a sustainable manner. There is a need to have continuous collaborative works between local people and forestry professionals for sustainable management. There is also a need to develop self-monitoring tool that allows local people to track the progress of forest management towards the goal of sustainability. Criteria, indicators, and verifiers are considered as self-monitoring tool to evaluate a sustainable community based forest management practices. Local people identified four criteria, 26 indicators and 60 verifiers for evaluating sustainable community based forest management. The identified criteria are found to be identical with the institutional top-down criteria. Similarly, wetland, grassland, recreation area in forest, motivational works towards forestry, and office management are new indicators suggested by local people to evaluate a sustainable community based forest management practices. Locally developed criteria, indicators and verifiers for sustainable community forest management can provide a local picture of what to consider for assessing a sustainable CBFM. Since the identified indicators are common mostly in buffer zone community forestry, community forestry and collaborative forestry they can be combined together to develop a single set of C&I and verifiers as a monitoring tool for evaluating a sustainable community based forest management practices.

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Annex 1: Locally identified criteria, indicators and verifiers

Criteria and indicators	**Verifiers**
Criterion 1. Extent of forest resources	
• Forest condition	• Composition of tree species • Regeneration status • Trees with different age classes • Canopy cover of forest • Good shape trees in forest • Forest area covered by destructive weeds and climber
• Forest growth and harvest	• Amount of timber and fuel wood harvested from forest in a year
• Presence of greenery	• Area covered by vegetation • Number of springs in forest
• Forest ground coverage	• Open area in forest floor
• Changes in forest areas over time	• Changed forest area into other land use over time
• Wildlife in forest	• Occurrence of wildlife in the area • Livestock killed/attacked by wildlife in the area
Criterion 2. Economic and social benefits	
• Awareness of people towards the importance of forestry	• Households showed up voluntarily to participate in forest related works • Number of meeting conducted for awareness • Trees on private land
• Participation of people in forestry activities	• Households showed up in general assembly • Households showed up in forest management activities
• Access to benefits	• Households obtained benefits
• Distribution of benefits	• Poor/marginalized households received benefits • Wood received by forest dependent people
• Motivation works towards forestry	• Welfare funds/allowance through forestry funds • Financial support through forestry funds to forest dependent people for Income Generation Activities (IGA) • Subsidy received through forestry funds for alternative energy • Scholarship through forestry funds
• Employment through forestry	• Local people hired as labour or staffs • Received skill oriented training • Households involved in IGA through forestry funds
• Generating common funds through forestry	• Amount of income generated through forest products • Amount of income generated through other sources such as recreation and tourism
• Mobilizing of forestry funds	• Investment through forestry funds
Criterion 3. Forest management practices	
• Silvicultural operations (*ban godne*)	• Silvicultural operations (*ban godne*) conducted regularly • Promoting valuable tree species
• Plantation activity	• Conducted plantation activity
• Incidence of forest fires	• Occurrence of forest fires in forest areas • Fire lines in forest

• Block divisions	• Block divisions in the forest
• Wetland in forest	• Prevalence of wetland in the forest • Ponds created artificially
• Grassland in forest	• Prevalence of grassland in the forest • Grassland created artificially
• Recreation area in forest	• Forest area allocated or created for recreation
Criterion 4. Institutional framework and governance	
• Policy	• Existence of national policy • Rules exist for forest products collection
• Leadership	• Punctuality in pre-determined programmes • Democratic mindset • Performed activities • Knowledge on forest policy • Sensitive on forest operational plan and CFUG constitution • Healthy
• Nature of the executive committee	• Inclusive (gender and marginalized people)
• Transparency	• Citizen charter • Public notice • Public hearing • Performed activities • Sub-committee
• Office management	• Office building • Office outlook • Office assistant • Meeting held

Pterospermum truncatolobatum Gagnepain (Sterculaceae): A new addition to the flora of Nepal

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Pterospermum truncatolobatum is an angiosperm indigenous to Southeast Asia. It is most likely to grow naturally along forested stream banks. The best growing conditions are a seasonally moist then dry climate with access to full sunlight. *Pterospermum* is an angiosperm that is traditionally included in the Sterculiaceae family; however, it is grouped in the expanded Malvaceae family as well.

The classification *Pterospermum* is based on two Greek words, Pteron and Sperma, meaning “winged seed”. To date, only 10 species names within the genus have accepted where as other twenty five species listed unresolved in the Plant List. About nine and five number of species under this genus *Pterospermum* have been reported from China and India. Only one species like *Pterospermum acerifolium* reported from Nepal (Press *et al*, 2000). During the course of plant collection this herbarium specimens was collected by Paudel, H. R. and Basnet B. K. (Fig.1). During the identification, this specimen did not match with any species of *Pterospermum* already reported from Nepal. After the detail study of specimens and available literatures (Shu, 2007), it has been identified as *Pterospermum truncatolobatum* Gagnepain.

Description of the species

Trees, to 16 m tall; bark black, striate. Branchlets densely yellow-brown stellate. Stipules palmately 3-5-fimbriate, densely hairy, caducous; petiole robust, 4-12 mm; leaf blade oblong-obovate in outline, usually irregularly lobed, 8-16 × 3.5-11 cm, leathery, abaxially densely gray-white or yellow-brown stellate tomentose, adaxially glabrous or minutely hairy along midrib, base cordate or obliquely cordate, apex truncate and 3-5-lobed, central lobe acute or acuminate, 1—2 cm. Flowers solitary, nearly sessile; epicalyx lobes fimbriate. Sepals linear, relatively thick, 4.5-6.5 × ca. 0.4 cm, abaxially densely brown tomentose, adaxially silvery white villous. Petals linear-falcate, 3-6 × 0.4-0.5 cm, base tapering. Stamens ca. 3.5 cm; staminodesfiliform, ca. 5 cm, glabrous. Ovary ovoid, hairy. Fruiting pedicel to 8 mm; capsule woody, ovoid or ovoid-cylindrical, prominently 5-angular and 5-grooved, ca. 12 × 7 cm, densely brown stellate tomentose, verrucose or not, base narrowed into 2-3 × ca. 1 cm stipe. Seeds 6-10 per locule, in 2 rows, 4-5.5 cm including wing, wing linear, up to 4.4 cm, apex obtuse or truncate. Fl. Jul.

Figure 1: Herbarium specimen of *Pterospermum truncatobatum*

Silviculture value: There is an array of common names for *Pterospermum truncatolobatum*, depending on the region where it is grown. It is commonly referred to as Kanak Champa, Muchakunda or Karnikar. Other common names include Bayur Tree, Maple-Leafed Bayur Tree,

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and Dinner Plate Tree. The reddish wood of the tree can be used for planking. Because the wood is soft, it is not considered to be very strong. However it is incredibly durable and somewhat flexible, making it perfect for planking and wooden boxes. The tree has been categories as fossil wood some of the species are under the IUCN red list. Mostly planted as an ornamental or shade tree, the leaves, flowers, and wood. The leaves can also serve as a primitive method of re-enforcing roofs and preventing leaks.

The pubescent under surface of the leaves is said to stop bleeding and can be used as tinder for a means of sparking fires. The flowers of the tree can serve as a pleasant perfume and can even keep away insects. The flowers also provide a number of medicinal uses. An effective tonic can be prepared, as well as being used as a cure for inflammation, ulcers, blood problems, and even tumors. Its bark is also supposed to be used in case of scabies and topical preparation like lipsticks.

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