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Tree Species Diversity, Composition, Stocks and Soil Nutrients Dynamics Due to Management Practice in Collaborative Forest

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ABSTRACT

*Sustainable forest management practices have been just initiated in Nepal but its effect on species diversity, composition and stock have not assessed yet. Thus, this research was objectively carried out to explore and assess the effects of forest management activities on tree species diversity, composition, and its growing stock. The 1-yr and 7-yr old felling series (FS) as well as control plot of three sub-compartments in Tilaurakot collaborative forest were selected as study site. Stratified random sampling was applied based on felling series. Altogether 76 samples were taken in nested quadrate having 20m*25m for trees, 10m*10m for poles, 5m*5m for saplings and 5m*2m for seedlings respectively. Soil samples were collected from 0-10, 10-20 and 20-30cm depths. Diameter at breast height (DBH) and height of plant were measured. Species richness, Alpha, Beta, Gamma, Simpson's diversity index, Shannon diversity index and evenness were calculated as well as soil nutrients particularly N, P, K and OM were estimated. The Simpson's diversity index, Shannon diversity index and evenness were found to be highest (0.740±0.052), (1.689±0.213) and (0.909±0.004) respectively in 1-yr old felling series at over storey on contrary it was found to be the highest (0.780 ± 0.035), (2.153 ± 0.261) and (0.935 ± 0.102) respectively at under storey in 7-yr old FS. However one-way ANOVA showed that there was no significant differences (p>0.05) in the indices values. The tree density and volume were found to be highest (62) and (84.71 m^3/ha) respectively in control plot. The soil N, P, K and OM were found to be highest at 0-10cm soil layer in all FS. The effects of management practices showed the variation in species diversity, composition and stock.*

Keywords: *Management, Diversity, Composition, Stock, Felling series.*

INTRODUCTION

Anthropogenic activities have been affecting the biological diversity. The dynamics of biological diversity of natural ecosystems become a global problem in second half of 20th century due to the intensive human activities (Mergani and Mergani, 2004). In 1992 the Earth summit was held and Convention on Biological Diversity (CBD) was approved by United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro aiming to conserve biodiversity, sustainable use of its components, and fair and equitable benefit sharing. Internationally, till the date more than 175 countries are mandated, as signatories to the United Nation's Convention on Biological Diversity, to prepare National Biodiversity Strategy and Action Plans (Balmer, 2002). With this respect, our neighboring countries like India, Bhutan, Pakistan, Thailand and China are also became a party of the CBD. Being a signatories parties Nepal has committed to conserve and utilize the country's unique biodiversity and biological resources on a sustainable basis (MoFSC, 2009). Ministry of Forests and Soil Conservation (MoFSC) has prepared the National Biodiversity Strategy and Action Plan (MoFSC, 2014). It provides a guiding framework for the management of Nepal's biodiversity and also to fulfill the country's international obligations (Pandey, and Maraseni, 2014).

Formerly, major objective of forest management was protection of forests and consequences are biodiversity conservation (Acharya, 2003, Sapkota, 2010) but in recent days, forests management options are heading towards the active silvicultural operations to produce good quality timber. The silvicultural practices are focused mainly on production of more timber removing the less valuable species in order to assure the quality plant species in next rotation. Consequently, only the valuable species remain for further growth that is a high threat to existence of other species. Some components and attributes of biodiversity are more sensitive than others to forest management activities (Gillium and Roberts, 1995). Silvicultural activities that are subjected to the forest change the tree species composition (Paudel and Sah, 2015). Therefore, it is important to monitor the forests regularly to determine whether the diversity is being maintained or not.

The maintenance of the forest is one of the important aspects of the forest management. Generally, shelter wood system is applied to harvest the mature and over trees. In addition, the thinning practices have been employed to assure the quality timber species. This has negative effect on biological diversity, thus the regular monitoring of biodiversity, composition and stock is essential (Roberts, 2013). The biodiversity, composition and stock varied at different stage and storey of the forests. It also varies from site to site even in same geographical region. The management practices have been subjected to shape the forest for the quality timber production. So, the obvious threat is loss of plant species diversity, its composition and stock at different site. Robert and Gillium, (1995) argued that edaphic factors especially soil nutrients like N, P, K including OM importantly affecting composition and stock of the forests. But, such type of study is very limited in Nepal. Thus, this research was objectively carried out to assess the effects of forest management activities on tree species diversity, composition, and its growing stock as well as variation in nutrition level.

Materials and Methods

Study site

Tilaurakot Collaborative Forests was selected for the study purposes (figure 1). This forest lies in Kapilvastu district, Province number 5 of Nepal which is renowned as the birth place of Lord Buddha.

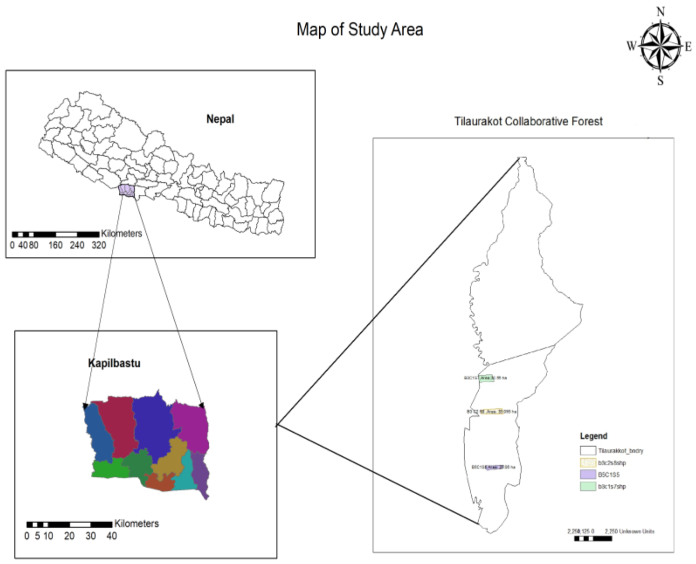

Fig 1. *Map of the Tilaurakot CFM*

The forest is situated at an elevation of 200 to 300 meters from mean sea level. Geographically, it is situated at 27° 35' 8.13"- 27° 45' 32.98" Latitude and 83° 1’ 56.78’’- 83°9' 6.49" Longitude. It extends from southern part of Arghakhanchi district in the North to the Ramghat and Tilaurakot in the South (DoF, 2008/2009)

Sampling Procedure and Sample Size

The study employed stratified random sampling for the data collection. The strata were 1-yr old felling series, 7-yr old felling series and control plot with three replications from sub-compartments B3C2S8, B3C1S7 and B5C1S5 of Tilaurakot Collaborative Forests, Kapilvastu, Nepal. In total, 76 sample plots were taken specifically 31 from control plot, 22 from 1-yr old felling series and 23 from 7-yr old felling series.

The number of sample plot was determined using following formula;

Number of plots (n) = $(t * 100*S/ W * e \%)^2$ ……………………………..eqn.

Where,

t = tabulated value of student-t (df-n-1, p=0.05), DF = degrees of freedom

S = standard deviation, W = Average weight of biomass

e = required accuracy (%)

Sample plots having dimension of 20 × 25 m^2, with three nested sub-plots of different sizes was laid in left corner of the biggest quadrate (Chaturbedi and Khanna 1982, Oli and Subedi, 2015).

Species Diversity Calculation

Species richness= n (number of species in the felling series was counted)

Alpha, Beta, Gamma diversity was also calculated

Shannon Wiener index (H') = $-\Sigma\ P_i \log p_i$........................... (i)

Simpson's diversity, (D) $=1-\Sigma\ P_i^2$........... (ii)

Evenness E=H/log (N)...................................... (iii)

Where,

P_i is the relative abundance of each species, i.e. the proportion of individuals of a given species relative to the total no. of individual in the community (Baumgartner, 2002).

Growing Stock Calculation

Number of species per unit area calculated

Volume calculation:

Growing Stock, GS = $(\pi\times DBH^2/4)\times h\times ff\times$ Tree quality.................. (v)

(DoF, 2004)

Where;

DBH = diameter at breast height (1.3m) from the ground level, his height of plant, ff is the form factor.

Yield Regulation by Melard's French Method

The growing stock is divided into 3 diameter/ age classes; the old class with trees corresponding 2/3 to full exploitable diameter (DBH>40cm), the medium class (20-40cm) with trees ranging in diameter from 1/3 to 2/3rd of the exploitable diameter and the young class (DBH<20cm) with tree less than 1/3rd of the exploitable diameter (Prakash, 2006). The two classes i.e. medium and old of the growing stock are enumerated, if the volumes are in the proportion of 3:5; the forest is considered as normal.

Lab Analysis

The soil fertility particularly soil nitrogen, potassium, phosphorus and Organic matter (DoAC, 2011). Specifically, N, P, K and OM were analyzed employing Kjeldahl method (1883), Olsen's and Somers method (1954) and Colorimetric method respectively (Walkley and Black, 1934)

Table 1. *Alpha, Beta and Gamma diversity*

Diversity types	B3C2S8			B3C1S7			B3C1S5		
	1-yr	**7-yr**	**CP**	**1-yr**	**7-yr**	**CP**	**1-yr**	**7-yr**	**CP**
Alpha diversity	14	15	17	12	12	13	13	13	10
Beta diversity	1-yr vs 7-yr, 11	7-yr vs CP, 10	1-yr vs CP, 5	1-yr vs 7-yr, 6	7-yr vs CP, 6	1-yr vs CP,6	1-yr vs 7-yr, 10	7-yr vs CP, 9	1-yr vs CP, 7
Gamma diversity	22			16			18		

The Simpson's diversity index was not found same in all felling series at seedling stage (**Error! Reference source not found.**). The highest (0.742 ± 0.018) value was found in 7-yr old felling series while the lowest (0.694 ± 0.011) in control plot. In the same manner, the Shannon Wiener diversity index was found to be highest (1.928 ± 0.111) in 7-yr old felling series whereas it was the lowest (1.686 ± 0.074) in control plot.

Similarly, Shannon Wiener evenness value was found to be the highest (0.747 ± 0.012) in 7-yr old felling series and it was the lowest (0.699 ± 0.021) in control plot. Statistically, one-way ANOVA showed that there was no significant differences among the felling series at seedling stage (p>0.05).

RESULTS AND DISCUSSION

Tree species richness and diversity in felling series

Result showed that the Highest (17) Alpha diversity was found in control plot of sub-compartment of B3C2S8 and the lowest (9) in 1-yr old felling series of sub-compartment B3C1S7 (**Error! Reference source not found.**). Similarly, Beta diversity was found to be the highest (11) in between 1-yr and 7-yr old felling series of sub-compartment B3C2S8 where as it was found to be the lowest (5) in between 1-yr old felling series and control plot of same sub-compartment. On the other hand, Gamma diversity also found to be highest (22) in sub-compartment B3C2S8 whereas it was found to be the lowest (16) in sub-compartment B3C1S7.

Table 2. *Mean diversity indices at seedling stage*

Management stage	Species richness	Simpson's diversity index	Shannon diversity index	Shannon evenness	Remarks
		Mean ± SE	Mean ± SE	Mean ± SE	
Mean diversity indices at seedling stage					
1-Yr.	17	0.722 ± 0.001	1.728 ± 0.050	0.746 ± 0.019	
7-Yr.	22	0.742 ± 0.018	1.928 ± 0.111	0.747 ± 0.012	
CP	17	0.694 ± 0.011	1.686 ± 0.074	0.699 ± 0.021	
Mean diversity indices at sapling stage					
1-Yr.	10	0.671 ± 0.078	1.426 ± 0.279	0.803 ± 0.062	
7-Yr.	17	0.780 ± 0.035	2.153 ± 0.261	0.935 ± 0.102	
CP	12	0.741 ± 0.062	1.678 ± 0.225	0.808 ± 0.052	
Mean diversity indices at pole stage					
1-Yr.	9	0.660 ± 0.176	1.689 ± 0.213	0.934 ± 0.009	
7-Yr.	11	0.603 ± 0.139	1.557 ± 0.074	0.900 ± 0.033	
CP	9	0.557 ± 0.124	1.342 ± 0.102	0.819± 0.031	
Mean diversity indices at pole stage					
1-Yr.	9	0.740 ± 0.052	1.410 ± 0.224	0.909 ± 0.004	
7-Yr.	11	0.654 ± 0.035	1.289 ± 0.117	0.768 ± 0.028	
CP	9	0.696 ± 0.059	1.371 ± 0.181	0.830 ± 0.046	

The estimated Simpson's diversity index was found to be the highest (0.780 ± 0.035) in 7-yr old felling series at sapling stage (**Error! Reference source not found.**). Similarly, Shannon diversity index value was found to be highest (2.153 ± 0.261) in 7-yr old felling series. Likewise, Shannon evenness value was found to be the highest (0.935 ± 0.102) in 7-yr old felling series. Statistically, one-way ANOVA showed that there was no significant differences in diversity indices among the felling series at sapling stage ($p>0.05$).

This was due to creation of favorable condition to regenerate new crop by opening the canopy. Author Pandey (2007) found similar types of result that the community managed forest has comparatively higher tree species diversity. Shrestha et al. (2010) and Acharya (2003) indicated that harvesting operations may create room for various species others than the dominant species (Nagaike, 2012). That makes the few tree species dominant in the forest. FRA/DFRS (2014) reported that, *S. robusta* as prominent species in Terai region of Nepal followed by other species.

Tree Species Composition and Growing Stock in Felling Series

The result showed that tree species richness was found to be highest in control plot at seedling stage because in control plot naturally every species has equal opportunity to grow. At pole stage, the highest (321/ha.) number of poles was found in 7-yr old felling series due to the advance growth. At sapling stage, density of *S. robusta* was found to be the highest (991/ha) in the 7-yr old felling series which was followed by *T. alata* (476/ha). One-way ANOVA showed that there was no significant differences in species composition among the felling series at sapling stage **(**$p>0.05$). Similar result was found by Awasthi et al., (2015) in Lumbini Collaborative Forest, Rupandehi, Nepal in unmanaged forest the number was found to be the highest (29) whereas it was only (23) in managed (Baral and Kartzensteiner, 2009).

At the tree stage, *S. robusta* was found dominant in all felling series which was followed by *T. alata*, *Lagerstromia parviflora* Roxb. *T.belerica* (**Error! Reference source not found.**). It was found to be the highest (26/ha) in control plot. Statistically, One-way ANOVA showed that there was no significant differences in species composition among the felling series at tree stage ($p>0.05$) the timber volume was the highest (84.71 m^3/ha) in the control plot. Webb and Gautam (2005) found the same result, the mature and semi-protected forest had a substantially high growing stock compared to managed stand due to the high density of large sized trees.

Yield Regulation by Melard's French Method

The growing stock of each felling series was divided into 3 diameter classes; the old class with trees corresponding 2/3 to full exploitable diameter (DBH>40cm), the medium class (20-40cm) with trees ranging in diameter from 1/3 to 2/3rd of the exploitable diameter and the young class (DBH<20cm) with tree less than 1/3rd of the exploitable diameter (Prakash, 2006). The two classes i.e. medium and old of the G.S were enumerated, if the volumes are in the proportion of 3:5; the forest is considered as normal.

FRA/DFS (2014) reported that, the mean stem volume of Terai region of Nepal is 161.66 m^3/ha and no any forest is normal in Nepal.

Table 3. *Ratio of the volume according to DBH class*

DBH class	Young (< 20)		Medium (20-40)		Old (> 40)		Ratio (Vol.) (1 : 3 : 5)
	N	Vol.	N	Vol.	N	Vol.	
1-yr. Felling series	12	0.85	14	6.75	3	5.55	1 : 7.94 : 6.53
7-yr. Felling series	16	1.27	19	9.4	5	7.15	1 : 7.40 : 5.63
Control plot	12	3.52	18	14.35	9	11.78	1 : 4.08 : 3.35

The result revealed that, in 1-yr. old felling series the ratio of the volume of medium and old class trees was found to be 7.94: 6.53. Similarly, in 7-yr old felling series the ratio was found to be 7.40: 5.63. In contrast, it was found to be 4.08: 3.35 in the control plot (Table 3).

Nutrition Availability in the Felling Series

Result showed that there was variability among the felling series in N, P and K. The highest (0.130 ± 0.005) Nitrogen % was available in the 1-yr old felling series in 0-10cm soil depth. Similarly, the phosphorus was found to be the highest (10.987 ± 0.687) in 0-10cm soil layer of 1-yr old felling (**Error! Reference source not found.**). As compared to soil Layer of other felling series it was found the highest in each layer of 1-yr old felling series. The Potassium was found to be the highest (279.933 ± 35.602) in 0-10cm soil depth of 7-yr old felling series. The highest (2.560 ± 0.139) organic matter % was found in 0-10cm soil layer of 1-yr old felling series. The effect of soil nutrients were varied in felling series along with depth. According to parameter (**Error! Reference source not found.**), in soil layer 0-10cm of 1-yr old and 7-yr old felling series the Nitrogen % availability was medium range (0.1-0.2). The soil nutrients vary according to site and their effect clearly affect on the plants growth (Jackson, 1994, Bandel and Meisinger 2000, Colangelo et al., 2013).

Table 4. *Mean N, P, K contents in felling series acc. to soil depth*

Felling series	N% (Mean ± SE)			Remarks
	0-10 cm	10-20 cm	20-30 cm	
1-yr old	0.130 ± 0.005	0.080 ± 0.020	0.073 ± 0.017	
7-yr old	0.100 ± 0.020	0.063 ± 0.003	0.050 ± 0.010	
Control plot	0.070 ± 0.017	0.067 ± 0.018	0.057 ± 0.012	
	P_2O_5 kg/ha. (Mean ± SE)			
1-yr old	10.987 ± 0.687	5.493 ± 1.373	5.493 ± 1.373	
7-yr old	8.827 ± 2.902	4.807 ± 0.687	4.120 ± 0.00	
Control plot	6.180 ± 1.189	5.493 ± 0.687	4.120 ± 0.00	
Organic Matetr %				
1-yr old	2.560 ± 0.139	1.563 ± 0.437	1.467 ± 0.408	
7-yr old	2.053 ± 0.429	1.260 ± 0.044	1.007 ± 0.204	
Control plot	1.473 ± 0.426	1.140 ± 0.246	1.127 ± 0.277	

CONCLUSIONS AND RECOMMENDATIONS

The tree species richness was found to be the highest in control plot. The diversity indices and evenness values were found to be highest in managed felling series. The highest numbers of poles were found in 7-yr old felling series at pole stage but the highest numbers of trees were

Found in control plot at tree stage. The stem volume was found to be highest in control plot. The N, P, K and OM were found more in upper soil layer (0-10cm) of each felling series whereas Bulk density was the lowest in upper layer (0-10cm). Regular and proper care should be employed during the management practices.

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