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Research Article

Evaluating Ecological Values and Carbon Stock in Trees Outside Forests (TOFs) in Terai Region of Nepal

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Abstract

The ecological and environmental functions performed by Trees Outside Forests are less concern in scientific community. Thus, this research was objectively conducted to assess importance value index (IVI), tree species diversity and carbon stock density. Dhangadimai Municipality of Siraha District, Nepal was selected as study site. The map of TOF was prepared and further categorized it into Group and Scattered plantation. Altogether 60 samples, specifically each 30 from Group and Scattered plantation, were collected using stratified random sampling measuring the diameter and height of the plants. Moreover, 240 soil samples were collected from 0-10, 10-30, 30-60 and 60-100 cm depths. The importance value index was estimated summing the value of relating basal area, density, and dominancy as well as Shannon wieners index, Simpson's diversity and Sorensen's Similarity Index were calculated. The biomass was calculated using equation of Chave et al., and it was converted into carbon. Walkley and Black Method was used to soil carbon. Total 22 and 33 tree species were found in Group and Scattered plantations, respectively. Mangifera indica, Eucalyptus camaldulensis, Dalbergia sissoo and Artocarpus lakoocha were prime tree species found in plantation site. The estimated IVI of Mangifera indica was the highest with 102.32 while this was the lowest 7.98 of Syzium cumunii in Group plantation but this value was the highest 64.46 of Dalbergia sissoo in scattered plantation. The Simpson and Shannon Wiener indices were 0.70 and 0.90 respectively in group plantation which were 0.84 and 2.45 correspondingly in scattered plantation. The biomass and carbon were approximately 447.14 ton/ha and 210.15ton/ha respectively in Group plantation. Calculated soil carbon was higher 51.49 ton/ha in scatter plantation. The highest soil carbon was about 16.63±2.14 ton/ha in 0-10 cm depth in scatter plantation and it was decreasing according to soil depth in scattered plantation. The study will be useful for policy formulation regarding biodiversity in TOF.

Keywords: Biomass, Carbon stock, Index of Value Index, Trees Outside Forests, Tree species diversity

Introduction

The life on the earth is interlinked with the available natural resources on the earth. Thus, natural resources are the key ornament. Tree resource whether it is inside the forest or outside the forest is one of the key components of natural resources because it performs several functions. Some vital functions are ecological importance, biodiversity conservation and carbon sequestration Trees available on lands but that is not considered as 'forests' or 'other wooded land' according to definition of forest is known as TOF (FAO 2005; Kumar 2006)[1,2]. Importantly, productive, and protective functions are major categories which a forest of

TOF performs as a broad. More specific, productive functions of TOF are production of fruits and timber, firewood and fodder in orchards, fields, and other agroforestry systems. On the other hand, protective functions comprise ecological and beautifying the landscape for instance trees around in parks, cities, and urban areas and even around the houses. Generally, the TOF is designed as discontinuously on farmland preferably known as scattered plantation while continuous planting pattern of trees literally considered as group and strip plantation (Alexandre et al. 1999)[3].

On the other hand, another important aspect of TOF forms the linkage and inter linkage with the disciplines. The most popular disciplines of TOF are agroforestry, Tongya considering the agronomy, silvipasture, horticulture, in home garden, etc in global context. Basically, the TOFs are one of crucial part of subsistence farming systems in developing country in particular including Nepal (Regmi and Garforth 2010)[4]. It TOF has ignorable role and that is environmental balance in rural areas at local, national, and global scales (Singh and Chand 2012; de Foresta et al. 2013) [5,6]. Another fact related TOF is land available or coverage or range, it is more growing in rural farmland in Asia to meet their requirement of timber, firewood, and fodder in certain level. . The forest resource assessment includes the TOF as important natural resource basically defining this term like in less than 20 m wide and available on the land 0.5 ha area in Nepal's context (Gurung et al. 2015)[7]. It is realizable fact about the common use of forest and TOF in Asian continents India, Pakistan, Bangladesh, Nepal, Bhutan, and Sri Lanka in particular. In this context, the TOFs in this content contribute significant whether it is about the ecological value including biodiversity and carbon sequestration. In fact, total area of this continent is of 4.13 million sq km with huge population 1,000 million approximately (Gurung and Temphel 2015)[8]. The acceptable fact is only 20 percent area is under the forest in this continent and minimum and maximum forest covering is 3.8 and 70 percent in Pakistan and Bhutan respectively. So, function of TOFs as ecological and environment is necessarily and importantly valuable (Schroeder 1994; Rawat et al. 2004Zhu et al. 1991)[9,10].

TOF is highly precious where the forest resource is scare and local people access on it is limitedly or probably restricted. This theory is applied in some districts in Terai, Nepal Amatya [11] and Siraha is one of best example in Nepal. Therefore, government Nepal continuously conducted the private plantation (TOF) promotion programme especially in Siraha district to meet the major demand of timber, fuelwood, and fodder (Gilmour1997; Garforth et al. 1999; Regmi1988)[12-14]. Planting the trees as TOFs performs ecological role and carbon sequestration in any part of the world FAO, Singh, and Chand& Herrera [5,15&16] including Nepal even in Siraha district as well and which has great scientific value. However, research regarding importance value index, tree species diversity, and carbon stock in TOF is not so far done. Therefore, this study was objectively done to evaluate the importance value index, tree species diversity index and carbon stock density in TOF.

Materials and Methods

Study Area

The ward no. 4, 5, 6 , 9,10 and 11of Dhangadimai Municipality of Siraha District of Nepal was selected as the study site Figure 1.The Latitude and Longitude range from 26.720 to 26.80° South and 86.34° to86.43° East respectively but area of study site was 8,034.7Km2. The overall climate is tropical having average annual temperature of 24.4 °C and total rainfall of 1275 mm [17]. In total approximately 22644 people are living in the study area (CBS, 2011)(Figure 2&3).

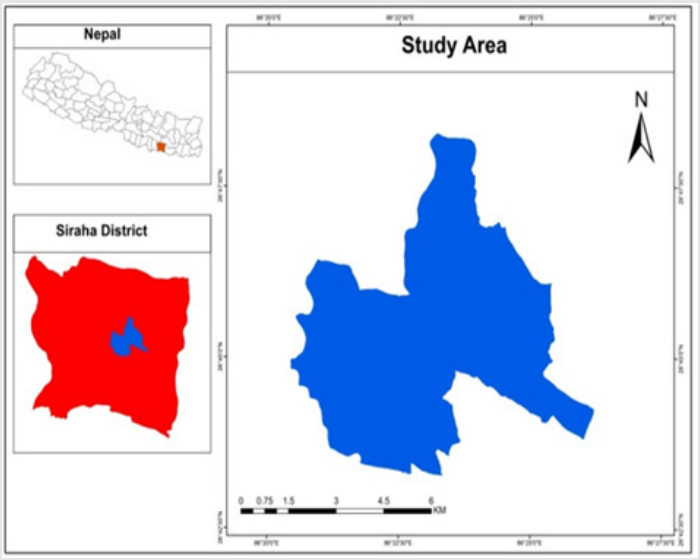

Figure 1: Map of the study site.

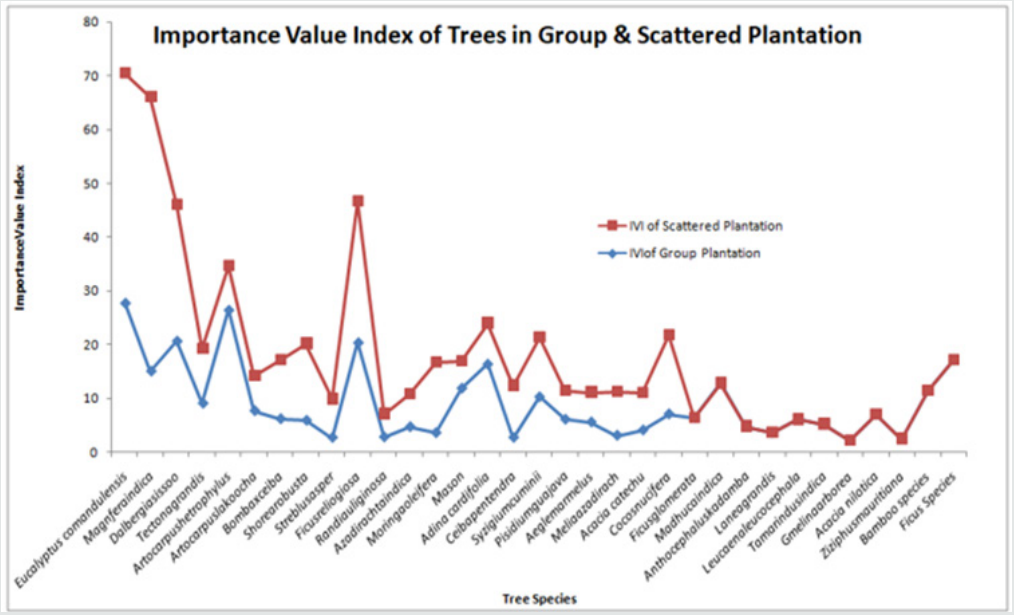

Figure 2: Calculation of IVI of TOFs species in Group and scattered plantation
Source: Field Survey, 2018.

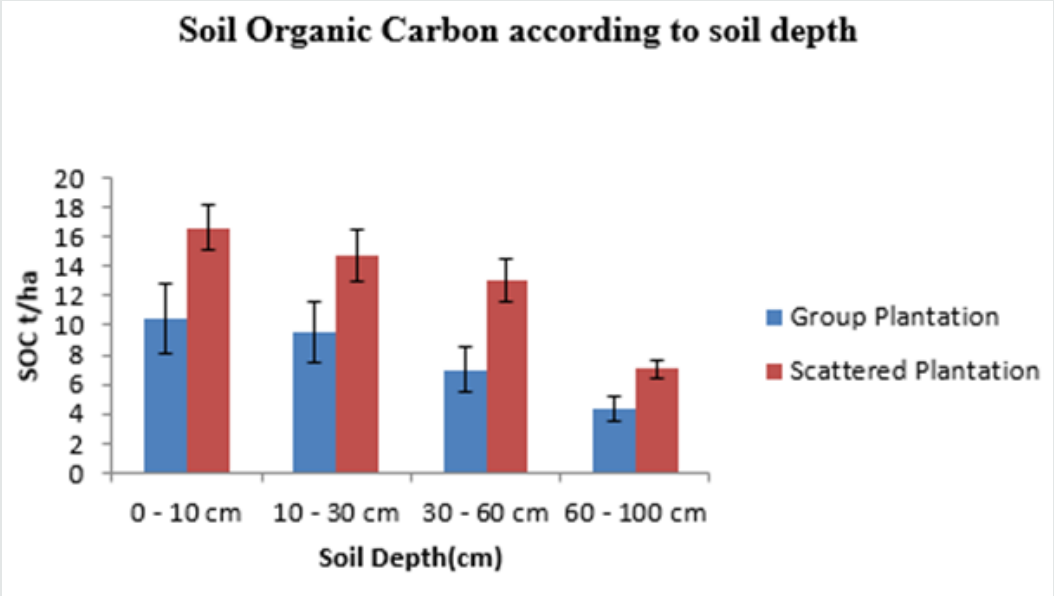

Figure 3: Soil Organic Carbon according to soil depth.

Methods

The preliminary survey, sampling design, data collection and its analysis were performed to accomplish this task. Preliminary survey was done to find TOF area so more specific some farmlands, roadside plantation, village woodlot, plantation on bank, orchard, and home garden were visited and sites were noted. Next, participatory map was prepared to identify and show TOF areas. Furthermore, the areas were surveyed using GPS receiver and maps were prepared accordingly. Then, the sites were stratified FSI, Rawat & FAO [10,18 & 19] into group and scattered according to nature of plantation.

First of all, 30 samples were allocating on the each maps of Group and scattered plantation. Furthermore, the GPS coordinates of all sample plots were uploaded in GPS receiver to navigate in the field. The plots having 32 X 32 m^2 area were laid in group plantation and these plots 50 X 50m^2 were established in scattered plantation for biophysical measurement which were and counting. So, Diameter at Breast Height (DBH >5 cm) and height were recorded,

plant species were noted, and their number were counted. The soil corer was used to soil samples from 0-10, 10-30, 30-60, 60-100cm depths Chabbra [20]. Total 240 soil samples were collected from the Centre of laid plot.

The importance value was calculated summing the relative density, basal area, and dominance.

Importance value index (IVI) was calculated using:

IVI = Relative density (N/ha)+ Relative BA/ha +Relative dominance (CA/ha).....(i)

The total value of IVI is 300. The value of total p percentage N/ha, percentage BA/ha and percentage CA/ha is 100% each [21].

The biodiversity indexes, Shannon wieners index, Simpson's diversity and Sorensen's Similarity Index were calculated using following equation.

Shannon wieners index (H') = -∑ Pi log (pi)..... (ii)

Simpson's diversity, (D) = 1- ∑ Pi^2.....(iii)

Sorensen's Similarity Index, SSI = 2c/ (S1 + S2)..... (iv)

Whereas, Pi= 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, S1= total no. of species recorded in the first community and S2= the total no. of species recorded in the second community,

c =the no. of species common to both communities (Baral and Katzensteiner2009; Balmer2002).

The basal area, volume and biomass was calculated.

Basal area= pD2´.....(v)

Volume= pD2´h ´¦¦/4..... (v)

Whereas p= 3.14,D = diameter at breast height (cm),h = height of the tree (m),¦¦ = form factor (0.5) ,Tree per ha = Total no. of tree / Total area [22].

The equation given by Chave [23] was applied to estimate above ground biomass and carbon stock of the TOF:

Above ground tree biomass in kg (AGTB) = 0.0509´r*D2*h.....(vi)

Above ground carbon content = 0.475×AGTB..... (vii)

Where, r=Dry wood Density (gc / m3), D=Diameter at breast height (cm), H= height of tree (m)

Carbon = Biomass x carbon %..... (viii)

The calculated biomass was further estimated using the default value 0.47 (MacDicken1997).

Soil Organic Carbon (SOC):

Soil organic carbon was analysed using Walkley and Black in the lab [24].

SOC = ρ* D* C%

Whereas SOC = soil organic carbon stock per unit area [t /ha], ρ = soil bulk density [g cm^{-3}],

D = the total depth at which the sample was taken [cm], and

%C = carbon concentration [%].

Results

Importance Value Index (IVI) of TOFs species in Group and Scattered plantation

The importance value index was varying according to tree species recorded in TOF. Total 22 and 33 tree species were recorded in group and scattered plantations respectively and 20 species were common in both plantations. The Mangifera indica performed the highest IVI with 51 but it was lowest of Mason having 5.0 in group plantation. On the other hand, it was the highest IVI of Eucalyptus comandulensis with 27.8 but the least IVI was only 2.2 of Gmelina arborea. Furthermore, the first rank of recorded of Mangifera indica in group plantation while the first rank was of Eucalyptus comandulensis in scattered plantation Table 1.

Table 1: Simpson's and Shannon Wiener index in Group and Scattered plantation.

S.N	Forest type	Sorensen Similarity Index Between species of group and scattered plantation	Simpson's index (D)	Shannon Wiener Diversity Index (H')
1	Group plantation	0.02	0.7	0.9
2	Scattered plantation		0.84	2.45

Tree species richness in Group and scattered plantation

The scattered plantation was rich in plant diversity as compared to group plantation. Specifically, Simpson's and Shannon Wiener indices were 0.84 and 2.45 respectively in scattered plantation and these indexes were 0.70 and 0.90 respectively in group plantation. The Mann- Whitney U and Wilcoxon test showed that there were significant differences in values of Simpson Index and Shannon Wiener Index between group and scattered plantation at 95% confidence level since P-value was less than 0.05 (P=0.00).Besides this, the Sorensen similarity index used to assess the similarity in both types of plantation (group and scattered plantation). The calculated SSI value of group plantation and scattered plantation was 0.020.

The density, basal area, volume, and carbon stock were varied according to species in group and scattered plantation in TOF. The highest density was recorded 115.23/ha having basal area 8.42 m^2/ha of Magnifera indica in group plantation It was followed by density107per ha having basal area 3.51 m^2/ha of Eucalyptus camaldulensis. So, the volume was also highest around 32.31 m^3/ha of Mangifera indica in group plantation. But the estimated biomass and carbon stock was the highest of Eucalyptus comaldulensis with 37.041 Ct/ha and 17.409 Ct/ha respectively in group plantation (Tables 2 & 3).

Table 2: Variation in growing stock and carbon density of Tree in Group and scattered plantation.

Tree Species	Group Plantation				Scattered Plantation			
	Density (N/ ha)	BA (m^2/ha)	Volume (m^3/ha)	C (t/ha)	Density (N/ ha)	BA (m^2/ha)	Volume (m^3/ha)	C (t/ha)
Eucalyptus comaldulensis	107.4219	3.5108	31.4037	17.4092	17.7333	0.6112	4.7951	2.6583
Mangifera indica	115.2344	8.4192	32.3087	13.5808	8.5333	0.2478	0.795	0.3342
Dalbergia sissoo	57.9427	1.2201	7.5994	3.611	13.7333	0.3258	1.5787	0.7502
Tectona grandis	5.5339	0.3196	3.3463	1.4678	5.2	0.0776	0.2972	0.1304
Artocarpus hetrophylus	5.5339	0.1739	0.5259	0.1458	0.8	0.1488	0.8185	0.2269
Artocarpus lakoocha	0.651	0.0166	0.1325	0.0517	1.0667	0.0711	0.3509	0.1368
Bombax ceiba	3.2552	0.199	1.005	0.2296	0.8	0.0232	0.1065	0.0243
Shorea robusta	2.6042	0.2295	2.2236	1.1921	0.1333	0.006	0.0241	0.0129
Streblus asper	0.3255	0.0135	0.027	0.0111	0.4	0.0071	0.0247	0.0102
Ficusreliogiosa	0.3255	0.0473	0.4018	0.0955	0.6667	0.1362	0.8852	0.2103
Randiauliginosa	0.3255	0.0083	0.029	0.0119	0.1333	0.0034	0.0119	0.0049
Azedirachtaindica	0.3255	0.0026	0.0128	0.0055	0.8	0.0068	0.034	0.0146
Moringa oleifera	0.3255	0.0118	0.0295	0.0047	1.2	0.0126	0.0342	0.0055
Trewianudiflora	1.6276	0.0128	0.0447	0.0184	6.6667	0.108	0.5064	0.2079
Acasia catechu	0.3255	0.0153	0.1381	0.0808	0	0	0	0
Adina cordifolia	0.3255	0.016	0.1438	0.0587	3.4667	0.4689	2.3821	0.9723
Ceibapentandra	1.3021	0.0614	0.3683	0.0516	0.1333	0.0007	0.0013	0.0002
Syziumcumuni	1.3021	0.0785	0.6081	0.2853	2.8	0.1233	0.4316	0.2025
Pisidiumguajava	0.651	0.0086	0.0346	0.0126	2.5333	0.0341	0.081	0.0296
Cocos nucifera	0.3255	0.0262	0.2094	0.1327	0	0	0	0
Eagle marmelus	0.3255	0.0026	0.0077	0.0035	0.1333	0.0042	0.0209	0.0096
Meliaozedirach	0.9766	0.0442	0.2651	0.0807	0.8	0.004	0.0121	0.0037
Wendlandiapuberula	0	0	0	0	1.8667	0.0202	0.0773	0.0316
Albezialebek	0	0	0	0	1.3333	0.0522	0.222	0.092
Ficusglomerata	0	0	0	0	0.1333	0.0082	0.0287	0.0068
Madhucaindica	0	0	0	0	0.6667	0.0669	0.3346	0.1855
Anthocephaluskadamba	0	0	0	0	0.4	0.0091	0.0424	0.0155
Laneagrandis	0	0	0	0	0.4	0.0084	0.0363	0.0155
Leucenaleococephala	0	0	0	0	1.6	0.0431	0.1416	0.0466

Tamarindusindica	0	0	0	0	0.1333	0.0046	0.0162	0.0128
Gmelinaarboera	0	0	0	0	0.8	0.0032	0.0066	0.0021
Acacia nilotica	0	0	0	0	0.2667	0.0084	0.0335	0.0169
Ziziphusmauritiana	0	0	0	0	0.4	0.005	0.0126	0.0071
Bamboo species	0	0	0	0	1.6	0.0985	0.5419	0.132
Ficusracemosa L.	0	0	0	0	0.1333	0.0203	0.1318	0.0313
Total	306.97	14.44	80.87	38.54	77.47	2.77	14.82	6.54

Table 3: Biomass and carbon stock according to plantation type.

	Plantation type	No	Mean ton/ha	Standard Deviation
Biomass	Group	6	74.52 ±20.39	49.94
	Scattered	20	1.33 ±0.47	2.12
Carbon	Group	6	35.03±9.58	23.47
	Scattered	20	0.63±0.22	1

The highest density was around 17.73/ha with basal area 0.61 m^2/ha of Eucalyptus camaldulensis which was followed by Dalbergia sissoo having the density and basal area 13.73 per ha and 0.33 m^2/ha respectively in scattered plantation, So, the stem volume, biomass and carbon stock was found to be highest of Eucalyptus camandulensis with 4.79 m3/ha, 5.6559 ton/ha and 2.6583 ton/ha respectively. The mean ± SE of biomass and carbon were 74.52 ± 20.39 and 35.03 ± 9.58respectively in group plantation which were only 1.33 ± 0.47 and 0.63 ± 0.22 respectively in scattered plantation.

Soil Organic Carbon

The soil carbon was varying according to group plantation and scattered plantation. The soil carbon was higher 51.5 ton/ha in scattered plantation, but it was only 31.28 ton/ ha in group plantation . The highest record of soil carbon was approximately 16.63±1.15 ton/ha in 0-10 cm but it was the lowest only 7.06±0.64 ton/ha 60-100 cm soil depth in scattered plantation.

Table 4: Summary of Soil Organic Carbon (SOC) (t ha^{-1}).

Soil depth cm	Group plantation		Scattered Plantation		*t-value*	p-value
	N	Mean ± SE	N	Mean ± SE		
0-10	30	10.45±2.38	30	16.63±1.50	2.57	0.013
30-Oct	30	9.5±2.07	30	14.76±1.79	2.77	0.007
30-60	30	7.00±1.57	30	13.05±1.51	1.93	0.058
60-100	30	4.33±0.85	30	7.06±0.64	1.93	0.058
Total	30	31.28±1.71	30	51.5±1.36	2.33	0.034

Statistically, t-test showed that, there was a significant difference in soil carbon at 0-10 and 10-30 cm depths between group and scattered plantation at 95% level of confidence which was slightly insignificant at higher depths. One-way ANOVA and Tokey's showed that, that there was a significant difference in the average SOC ($p < 0.05$) according to soil depths.

Discussions

Tree Importance Value Index (IVI) and Species Diversity

The IVI record of Mangifera indica species was found to be 102.32 the highest in group plantation but this of Dalbergia sissoo was found to be 64.46 the highest IVI in scattered plantation. The reason behind this was preference of the species by the farmers in group and scattered plantation. The study done by Mandal [25] in collaborative forest showed that the highest IVI was of Shorea robusta. The authors specified, the IVIs in Tuteshwarnath Bardibash – Gadhanta and Banke Mahara CFMs they were 68.59, 62.22, 61.65 respectively. Another study done in India showed that the Importance value index of (IVI) of Acacia catechu was 46.47, Albizia amara was 53.63, Anogeiss uslatifolia was 24.10 [26]. The IVIs of Ficus ovate was some species were 43.56, and this value of Eucalyptus camaldulensis was 10.11[27].

Singh [28] did research on IVI and carbon stock separately ignoring rank of IVI in the forest. Another study done by Balinga [29] in Africa showed that, the IVIs of Alstonia boonei, Strychnos innocua and Albizia adianthifolia were 16.86, 17.46 and 17.33, respectively. Another study done by Meng [30] in China showed that the IVIs of Lannea grandis,Dillenia pentagyna and Syzygium

cumini was 19.78, 16.71 and16.58, respectively. The study done in Nepal showed IVI of Shorea robusta was 259.2, IVI of Bombax ceiba was 96.84 [31]. However, it was quite gap in ranking of forest species based on IVI and carbon of plant species in Tarai, Nepal.

The record of DFO [17] showed that Dalbergia sissoo, Melia azedarach, Albizia spp. and Mangifera indica (Mango) are the most common plantation species in Terai. Diverse planted tree species in TOF add valuable diversity to sustain the farming system in long term [13,32]. Same principles were supported in Nepal's private plantation as well Gilmour, Regmi & Garforth [12-14] so there is increasing trend of plantation in as an agro-forestry model [33,34].

The tree biodiversity TOF in our study sites. The research done by Bashar [35] showed that Shanon diversity index was very high 3.24 of fruit species in Bangladeshi homegardens. Another research done by Sellathurai [36] revealed that for Sri Lanka this index was 3.93. Similar research done by Das [37] depicted that there were more than 60 species in farmland of eastern Nepal. Similar research done by Carter [33] revealed 101 tree species in a study conducted in middle hills of Nepal. There were 127 tree species in the mid-hills and simply reveals that farmland in the hilly region conserve more tree species than other region like Terai Kharal and Oli [38]. The study done by Goenster [39], showed that there were 103 plant species in agroforestry in Africa. The authors found that, mean Shannon index was 1.32 but this index was 0.8 in indigenous fruit tree species. The values were very close with the findings of our research. .These values were differed from our study. The reason behind this may be because of limit choice of farmer to plant the tree species. The farmers are more interested to plant Mangifera indica in group plantation while they are planting more Eucalyptus camaldulensis for fruits and getting timber fastly respectively. However, the study done by Amatya and Shresth [40] stated that farmers in Terai have planted fruits species as Mangifera indica, Artocarpus heterophyllus and Syzium cumuni in their farm while Eucalyptus camaldulensis and Dalbergia sissoo, Tectona grandis are as forest tree and timber species in Tarai, this finding is matching with our study. The previous study showed that total number of species was 35 in agro-forestry system in India [41].The reasons of similarity and differences in the findings, may be because of the effect of bioclimatic and geographical factors too Nicolas [42]. Another reason may, hilly farmers have more choice to fodder trees in Nepal because they have more cattle [43].

Growing Stocks, Biomass and Carbon stocks

The growing stock (volume) of TOF was varied according to number of stem/ha, age of stem, soil condition, species characteristic and silvicultural operations carried out for the TOF. The estimated growing stock was 178 m^3/ha (DFRS, 2014), according to national inventory which is contrary to our finding. The research done by Mandal [25] stated that 148ton/ha,77.71ton/ha and 30.34 ton/ha carbon biomass of 8 years of Eucalyptus camaldulensis in Sita community plantation forest, Shreepur public plantation and Bisbitty public plantation forest respectively. Another study showed that the carbon stock of 7 year plantation of Eucalyptus camaldulensis was 35t·ha^{-1} in a very good site [40]. The study done by Sah [44] showed that the carbon stock was varied particularly 57 ton/ha in Newardanda community forest, 81.28 ton/ha in Markawura community forest and 50.03 ton/ha in Galtar community forest, these findings are somehow similar to our research work.

Soil Organic Carbon (SOC)

The soil carbon was found higher in scattered plantation compared to group plantation; the probable reason behind this may be due to use of compost fertilizers as well as no or limit collection of litter. Another important aspect of this research showed that the soil carbon is decreasing according to soil depths which are supported by several studies such as findings of Shukla [45] and IPCC [46] were similar. Moreover, the soil carbon is rich in agroforestry system than it in agriculture areas [32]. Some studies done by Gautam [47] showed that organic carbon content ranges from 33.2 to 55.5 t ha^{-1} and from 35 to 74.6 t ha^{-1} in annual cropping system and in the plantation orchard respectively [46-53]. More specific, soil organic carbon was the highest in naturally grown forest with 53.2 t per ha which was followed by this in vegetable grown field having 52.6 t ha^{-1}. Additionally, it was 34 t ha^{-1} soil carbon at 0-10 cm depth in grazing land which was followed by the value 20 t ha-1 in cultivated upland (Bari), (14 t ha^{-1} in forestland and only 12 t ha^{-1} in level terraces (Khet) Gautam [45]. Some of these findings are matching with our research result may be due to similar geographical and climatic condition [54-56].

Conclusion

More tree species diversity was found in scattered plantation than it in group plantation. Major tree species of group plantation were Mangifera indica, Dalbergia sisoo, Tectona grandis and Eucalyptus camaldunsis. The tree diversity was higher in scattered plantation than it in group plantation. The IVI record of Mangifera indica was found to be highest in group plantation and this of Eucalyptus camaldulensis was the highest in scattered plantation. The basal area, volume and carbon stock was found to be higher in group in comparison to scattered plantation. The soil carbon was rich in agroforestry system and it was also found high in scattered plantation. Therefore, this study will be useful document for policy maker and scientific community especially interest of TOF. However, intensive studies are required in agroforestry system in other parts of Nepal.

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