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EFFECTS OF FOREST CARBON ON ECOLOGICAL VALUE OF SPECIES IN COLLABORATIVE FORESTS, TARAI, NEPAL

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Abstract

*There is an imperative interrelationship between people and forests however forests loss is continued which causes several complexities. This research was objectively done to show the effects of carbon stock on species ranking in collaborative forests (CFMs). The randomized block design (RBD) was set and stratified random sampling was applied to collect the biophysical data. Total 33, 32 and 31 samples were collected from Banke- Maraha, Tuteshwarnath and Gadhanta- Bardibash CFMs respectively; establishing 20*25m^2 plot for trees using GPS coordinates. The height and diameter of plants were measured. Additionally, frequency and density of plant species were also recorded. Latter biomass was calculated using equation by Chave et al. and importance value index (IVI) was also calculated to prioritize the species. Additionally, mix rank was also estimated by using IVI and carbon to evaluate effects of carbon on species ranking. It showed that, estimated highest IVI was 68.59 in Shorea robusta in Tuteshwarnath CFM. The carbon stock of Shorea robusta was the highest 50.43±0.43 t ha^{-1} in Gadhanta- Bardibash CFM. Total 11 species like Dalbergia latifolia, Schleichera trijuga, Croton roxburghii and Acacia catechu were promoted their rank under mix criteria. This showed that there was effect of carbon on species ranking.*

Keywords: *IVI; Forest carbon; Ranking ecological value; Promotion*

Introduction

There is imperative interrelationship between people and forests [1, 2] because forests are very benign to them. In fact, the green forests are working as tireless apparatus of oxygen production which is the precious life gas for living beings [3]. Forests produce timber and non-timber products for people. Besides, the forests function as ecosystem services, biodiversity kit and capture the CO_2 produced during the respiration process of living beings [4, 5]. This is why, life is impossible without green forests on the planet [6, 7]. However, people have been involved in the destruction and deterioration of the forests.

Apparently, deforestations rate is alarming in the world, region and local level. Globally, estimated annual deforestation was -0.13% between 2000 and 2010 but it was positive change 0.28% in Asia [8]. Moreover, the annual forest area loss in Terai, Nepal was 0.40% in between 1991 to 2010 [9] and was about 1.7% in between 1978 to 1994. Thus, the global deforestation contributes 18-20% sources of greenhouse gas emissions annually. Meanwhile, only tropical

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deforestation including Nepal shares about 25% of anthropogenic carbon emissions which is the leading cause of species extinctions [10]. The prime cause of this situation is increasing population and their demand for better future.

People and their poverty are equally responsible for mismanagement of forests [11]. Globally, middle class population expanded from 26% to 58% in between 1990 to 2010. In reality about 925 million people were undernourished in the world in 2010 [12]. Meanwhile, about1.57 billion people or more than 30% of the population of the 104 countries counting Nepal live in multidimensional poverty [13]. About 60 million people (especially indigenous peoples) are wholly dependent on forests for subsistence livelihood [12, 14]. So, only managing the forests is not the reliable solution to reverse the degraded and deforested lands without managing these people. Otherwise consequences may be more serious to living beings than the past.

Unfortunately, uncountable natural as well as artificial calamities have been observed these days which demands better alternative options to resolve them. Some examples are land degradation, flood, mass slides, natural disaster and warming and climate change that directly damage the ecosystem services like biodiversity and biomass [15]. Therefore, opportunity should be searched to use and manage the forest resource wisely through people's participation [16]. One of the compelling ways may be exploration of ecological value of a particular species in the forests ecosystem [16]. Equally, the carbon sequestration, which is the prime element of as ecosystem services, by particular species and their effect on ecological process may be the other way. These points may help people to know and realize the real value of plants species diversity and their contributions in carbon sequestration and ultimately in climate change. This research tries to cover these aspects because such types of works were rarely found and in fact they were lacking too in Nepal.

Thus, this research was objectively carried out to explore the ecological value of forest species, assess the carbon stock according to plant species in collaborative forests and to evaluate the effects of carbon on species ranking in these forests.

Materials and Methods

The methods include study site, sampling process, data collection and data analysis.

Study site

Mahottari district was selected for study area. This district is situated at 26° 36' to 28° 10' North and 85° 41' to 85° 57' East in central part of Nepal (Fig.1).

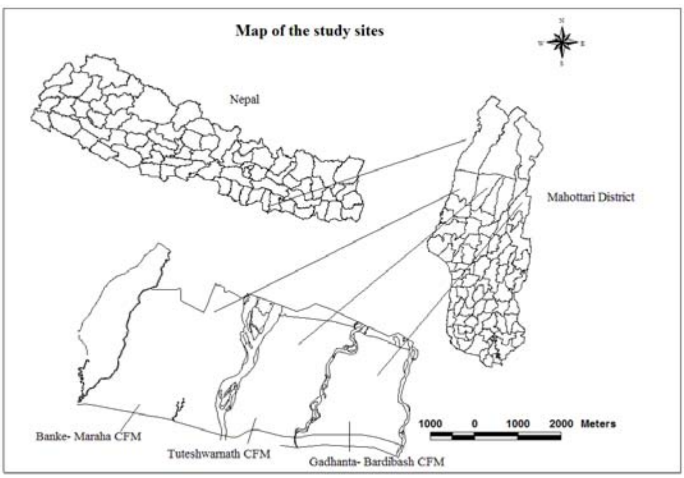

Fig. 1. Map of the study areas

The temperature ranges between 20-25° Celsius and average annual rainfall recorded between 1100-3500 mm.. Specifically, 3 collaborative forests namely Banke -Maraha, Tuteshwarnath and Gadhanta -Bardibash collaborative forests (CFMs) were selected for study site which have areas 2006, 1334 and 1450 ha respectively. The main species of these forests were Sal (*Shorea robusta*) and other major associate species were Saj (*Terminalia tomentosa*), Botdhairo (*Lagerstroemia parviflora*), Harro (*Terminalia chebula*) and Barro (*Terminalia belerica*).

Sampling process

All selected collaborative forests were surveyed using GPS GARMIN eTrex and maps were prepared using ArcGIS ArcMAP 10. Then, these forest areas were stratified into 3 strata like regeneration, pole and tree using the participatory rural appraisal sketch and GIS maps together. Each stratum was considered as block and sample plots were randomly distributed on each stratum setting the random block design (RBD) applying stratified random sampling.

After that, the number of sample plots was fixed using the pilot sampling method for each stratum [17]. For this purpose at least 5-15 sample plots were taken from each stratum of collaborative forest. Moreover, the typical species area curve was also considered so that the number of plant species may not be missed during sampling. Latter, the diameter at breast height (DBH) and height were measured to calculate the biomass. This method is based on co-efficient of variance. Hence, altogether, 96 sample plots were fixed using following equation for collaborative forests. Out of them, 32, 33 and 31 samples were allocated for Banke- Maraha, Tuteshwarnath and Gadhanta –Bardibas CFMs respectively.

Required number of sample plots (N) = $(CV^{*}t/E)^2$

Where, CV is the coefficient of variation of biomass $=S/\bar{x}$

Standard deviation, $s = \sqrt{\sum \frac{(x-\bar{x})^2}{n-1}}$,whereas x is the biomass of trees

t = value of Student's t-distribution Table at n-1 degree of freedom (df) at 10% probability but in (n-1), n denotes number of sample plots taken for pilot sample that is 10-15.

$E = \frac{S}{\sqrt{n}}$;

Where, E is the Sampling error at 10%, S is the standard deviation [18]. Next, the centre point coordinates of sample plots were noted from the map and the coordinates were uploaded in GPS in order to establish the plots in the field through navigating them. Here, the plot sizes were laid out to the nature of the stratum such as $20x25m^2$ for tree stratum and simultaneously nested plots $10x10m^2$ for pole and $5x5m^2$ for regeneration stratum.

Data collection

Then, the species wise data were collected from the established sample plots. The species' nomenclature, their frequency and number of occurrence were noted as well as their height and diameters were also measured. In addition, samples of regeneration particularly 1cm<DBH <5cm were collected in separate plastic bag and their fresh weight was taken and packed for lab analysis.

Data analysis

The data analysis was centered on biomass, Importance vegetation index (IVI) calculation and statistical test.

The biomass of plants having DBH>5cm was calculated using equation like

$AGTB = 0.0509 x \rho D^2H$ [19] but the biomass of plants with DBH<5cm was estimated by drying the collected samples in oven. Then, total biomass was converted into carbon multiplying with 0.47 [20].

IVI= relative density+ relative frequency + relative basal area

$$Density = \frac{\text{Total number of individuals of a species in all sample plots}}{\text{Total number of sample plots studied}}$$

$$\text{Frequency} = \frac{\text{Number of sample plots in which the species occured}}{\text{Total number of sample plots studied}}$$

$$\text{Basal Area} = \frac{\pi D^2}{4}$$

Besides, the relative density, relative frequency and relative basal area were calculated in percentage. Thus, the total value of IVI was 300.

Latter, rank was calculated for each species based on IVI, carbon and mix (carbon % + IVI %). The carbon stocks of some valuable species were compared among collaborative forests. At the same time the ranking of plant species based especially on mix and carbon(C) was compared to evaluate the effect of carbon stock on species ranking.

Statistically, the data of carbon stock of some valuable species were analyzed using IBM SPSS 20. Specifically, the record of carbon of each species was evaluated for normality test using Shapiro-Wilk test which showed that the record of carbon stocks of the plant species were not normal except record of *Shorea robusta*. Therefore non- parametric Kruskal Wallis test was applied to compare the species wise carbon stocks while one way ANOVA and multiple comparison Tuky's test were used to compare the carbon stocks of *Shorea robusta* among these forests.

Results and Discussion

The following results were drawn to meet the research objectives. They are: a. IVI and records of carbon stock in collaborative forests; b. comparison of carbon stocks of major species in collaborative forests; c. ranking of the species based on mix, IVI and carbon and d. evaluation of effects of carbon on plant species ranking.

IVI and records of carbon stock in collaborative forests

The IVI, carbon stock and their interrelation are importantly evaluated in the collaborative forests.

IVI of plant species in collaborative forests

The results showed that IVIs of plant species were differed according to collaborative forests. Specifically, the highest IVI was recorded for *Shorea robusta* in all collaborative forests. They were 68.59, 62.22 and 61.65 in Tuteshwarnath Bardibash –Gadhanta and Banke – Maraha CFMs. Additionaly, there were some more high records of IVIs of *Terminalia tomentosa* in all collaborative forests with 50.87, 52.56 and 47.09 in Bardibash – Gadhanta, Tuteshwarnath and Banke – Maraha CFMs respectively. Meanwhile, some species namely *Lagerstroemia parviflora, Anogeissus latifolia* and *Eugenia jambolana* showed 10<IVI<40. However, other species showed very less IVI < 5 for instance *Dillenia indica, Eucalyptus camaldulensis, Bridelia retusa, Aegle marmelous, Alstonia scholaris, Anthocephalus chinensis* and *Schleichera trijuga* (Figure 2). In reality, the reliable reason for high IVI of *Shorea robusta* was due to its dominancy in the research site. Remarkably, a study done in Chitwan, Nepal also showed the highest IVI about 39.71 of *Shorea robusta* [21]. In addition, the research done in Karnataka, India showed that the IVI of *Anogeissus latifolia* was 24.10 [22] which was matching with the estimated IVI of this species of present research too. Generally, high dominant species have high IVI [23].

Species wise carbon stock

The species wise carbon stock was varied in the collaborative forests because the total carbon stock was also not same in these forests. The estimated total carbon stock of all species was 110.14±0.42t·ha^{-1} in Banke - Maraha CFM, 136.44±0.46t·ha^{-1} in Tuteshwarnath CFM and 173.49±0.33t·ha^{-1} in Gadhant – Bardibash CFM. Specifically, the highest carbon stock was recorded in *Shorea robusta* with 50.43±0.43 t ha^{-1} in Gadhanta - Bardibash CFM. Other higher values were recorded in same species with 44.87± 0.24t·ha^{-1} in Tuteshwarnath CFM and 35.93 ±0.32t·ha^{-1} in Banke Maraha CFM. On the other hand, the lowest value of carbon stock about

0.01t·ha^{-1} was found in *Desmodium oojeinense* in Gadhanta - Bardibash CFM (Table 1). Infact the reason of the higher value of carbon stock in *Shorea robusta* was because of the dominance of this species in these forests. The report of Tarai [24] showed the estimated carbon stock of *Shorea robusta* was 52.31t·ha^{-1}, which value is quite similar to the estimated carbon stock of same species in Gadhanta - Bardibash CFM. Additionally, same report showed that the carbon stock of *Mallotus philipinensis* was 2.45t·ha^{-1}, which was also near to the value of carbon stock of same species in Banke - Maraha and Gadhanta - Bardibash CFMs.

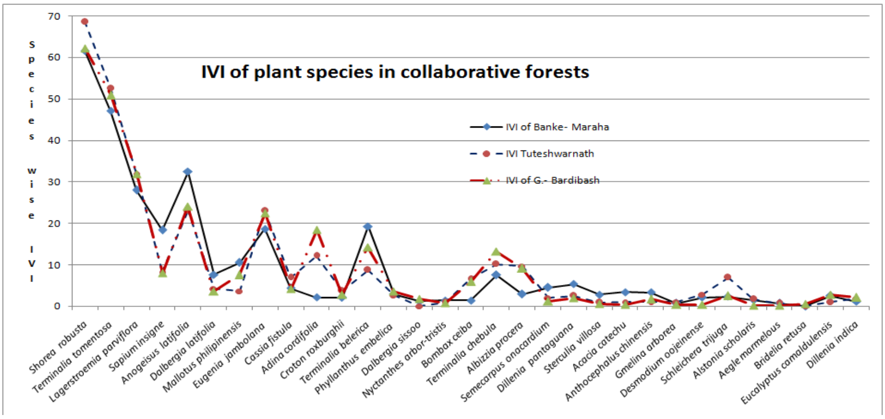

Fig. 2. IVI of different species in collaborative forests

Table 1. Carbon stock of plant species in collaborative forests

Species	Banke -Maraha	Tuteshwarnath	Gadhant-Bardibash
Shorea robusta	35.93±0.32	44.87±0.42	50.43±0.43
Terminalia tomentosa	25.50 ±0.28	34.49±0.38	36.79±0.38
Lagerstroemia parviflora	11.37±0.21	18.72±0.32	19.87±0.32
Sapium insigne	3.27±0.06	2.44±0.02	1.87±0.02
Anogeisus latifolia	9.80±0.17	11.28±0.28	15.40±0.28
Dalbergia latifolia	0.84	0.68±0.01	0.45±0.01
Mallotus philipinensis	2.55±0.04	0.87±0.06	2.36±0.06
Eugenia jambolana	7.40±0.21	10.14±0.29	13.66±0.29
Cassia fistula	0.32	1.40±0.03	0.59
Adina cordifolia	0.16	2.26±0.20	7.34±0.20
Croton roxburghii	0.15	0.21	0.15
Terminalia belerica	4.37±0.15	1.83±0.22	7.54±0.21
Phyllanthus embelica	0.20	0.23	0.88
Dalbergia sissoo	0.07	0.00	0.17
Nyctanthes arbor-tristis	0.07	0.07	0.07
Bombax ceiba	0.13	1.27±0.18	3.87±0.18
Terminalia chebula	3.42±0.16	1.47±0.16	5.35±0.16
Albizzia procera	1.65±0.10	2.13±0.17	4.06±0.17
Semecarpus onacardium	0.62	0.12	0.10
Dillenia pantaguana	0.83	0.43	0.23
Sterculia villosa	0.12	0.02	0.03
Acacia catechu	0.28	0.02	0.02
Anthocephalus chinensis	0.28	0.02	0.37
Gmelina arborea	0.02	0.02	0.02
Desmodium oojeinense	0.13	0.24	0.01
Schleichera trijuga	0.06	0.79	0.49
Alstonia scholaris	0.09	0.09	0.00
Aegle marmelous	0.02	0.02	0.00
Bridelia retusa	0.00	0.00	0.02
Eucalyptus camaldulensis	0.36	0.18	1.21
Dillenia indica	0.13	0.13	0.14

Note: 0 value showed absent of the species in the forests.

IVI and species wise carbon stock interrelation

The result showed that the higher the carbon, the higher was the IVI of plant species but it was differed too in many cases. For example the species like *Shorea robusta, Terminalia tomentosa* and *Lagerstroemia parviflora* showed the high carbon stock and high IVI too (Table 1 and figure 2). However, this was differed for *Sapium insigne* which showed less carbon stock about 3.27t·ha^{-1} and the estimated IVI were 18.35 in Banke - Maraha CFM. Similarly, the estimated carbon stock of same species was only 2.44t·ha^{-1} but the IVIs was 8.27 in Tuteshwarnath CFM. At the same time, the carbon stock was 1.87t·ha^{-1} while IVI noted 7.98 in Gadhant-Bardibash CFM. Same complexity was observed for carbon stock and IVI of *Eugenia jambolana* and *Terminalia belerica* too. It may be because of "the IVI calculation is based on relative BA which includes only the DBH of the plant, relative species density and frequency but carbon estimation preferably includes DBH, height, wood density of the plant. However, some dominant species have high IVI and normally they have high biomass too [25 to 28]. In this complexity, the prioritization of the plant species based on IVI may create the biased perception for climate change worker who is especially functioning for forests enhancement as an ecosystem services.

Comparison of carbon stocks of major species in collaborative forests

There was not too much variation in carbon stock of major species in these forests. Since the p-values were greater than 0.05, the ANOVA (parametric test) and Kruskal Wallis (non parametric one way ANOVA) test showed there was no significant differences in species wise carbon stock in these forests at 5% level of significant except *Lagerstroemia parviflora* (Table 2). The reason of not variation of species wise carbon may be due to site quality, dominance of more or less same aged plants. However, it is interesting to show how the rank of these important species varied.

Table 2. Comparison of carbon of major species

Plant Spp	Parametric test (p- value)		Non- parametric (p- value)	
	ANOVA	Tukey's test	Kruskal Wallis	Multiple comparison
Shorea robusta	0.21	NA		
Terminalia tomentosa			0.43	NA
Lagerstroemia parviflora			0.03	All differed
Sapium insigne			0.93	NA
Anogeisus latifolia			0.80	NA
Dalbergia latifolia			0.66	NA
Mallotus philipinensis			0.21	NA
Eugenia jambolana			0.21	NA
Terminalia belerica			0.44	NA
Terminalia chebula			0.34	NA

Rank of the species based on mix, IVI and carbon

Some species showed same rank based on the carbon, IVI and mix (carbon +IVI) but some species showed different results too. Specifically, *Shorea robusta* and *Terminalia tomentosa* showed same rank 1 and 2 respectively following both criteria. The other examples of the same ranks were found for *Gmelina arborea, Bridelia retusa* and *Aegle marmelous* in Banke - Maraha and Tuteshwarnath CFM. However, the ranking of some important species were differed too. Such as, the ranks of *Terminalia chebula* were 9, 10 and 7 in Banke- Maraha CFM based on mix, IVI and carbon respectively which were 9, 7 and 10 in Tuteshwarnath CFM. Same variations were found in ranking of *Dalbergia latifolia, Albizzia procera, Acacia catechu* and *Anthocephalus chinensis* too.

These create the uncertainty whether the species prioritized based on IVI or based on carbon stock. Particularly, *Sapium insigne* was ranked 7 under IVI but ranked 8 under carbon in

Banke - Maraha CFM. Similarly, this species was ranked 10 under IVI but it was ranked 6 under carbon in Tuteshwarnath CFM while it was ranked 10 under IVI and 12 under carbon in Gadhanta - Bardibash CFM. Similar complexities were observed for *Mallotus philipinensis*, *Terminalia belerica*, *Dillenia pantaguana*, *Albizzia procera* and *Semecarpus onacardium.* These obscurities were challenging to work for biodiversity and carbon. Thus the mix criterion was proposed to prioritize especially valuing the record of carbon too (Table 3).

Table 3. Species ranking in collaborative forests

Species/ Rank base	Banke- Maraha CFM			Tuteshwarnath CFM			Gadhanta – Bardibash CFM		
	Mix	IVI	C	Mix	IVI	C	Mix	IVI	C
Shorea robusta	1	1	1	1	1	1	1	1	1
Terminalia tomentosa	2	2	2	2	2	2	2	2	2
Anogeisus latifolia	3	3	4	3	3	3	4	4	4
Lagerstroemia parviflora	4	4	3	4	4	4	3	3	3
Eugenia jambolana	5	6	5	5	5	5	5	5	5
Terminalia belerica	6	5	6	10	9	9	7	7	6
Sapium insigne	7	7	8	8	10	6	12	10	12
Mallotus philipinensis	8	8	9	15	16	13	11	11	11
Terminalia chebula	9	10	7	9	7	10	8	8	8
Dalbergia latifolia	10	9	11	14	14	15	16	15	17
Dillenia pantaguana	11	11	12	17	19	16	19	20	19
Albizzia procera	12	17	10	7	8	8	9	9	9
Semecarpus onacardium	13	12	13	20	20	22	23	23	23
Cassia fistula	14	13	15	11	11	11	13	13	15
Acacia catechu	15	14	16	24	23	26	27	27	26
Anthocephalus chinensis	16	15	17	25	24	27	21	22	18
Phyllanthus embelica	17	16	18	19	18	18	14	14	14
Eucalyptus camaldulensis	18	19	14	23	26	20	15	16	13
Sterculia villosa	19	18	24	28	27	25	25	25	25
Adina cordifolia	20	21	19	6	6	7	6	6	7
Schleichera trijuga	21	20	28	13	12	14	17	18	16
Croton roxburghii	22	23	20	16	15	19	18	17	21
Desmodium oojeinense	23	22	22	18	17	17	29	29	29
Bombax ceiba	24	26	21	12	13	12	10	12	10
<u>*Alstonia scholaris*</u>	25	24	25	22	22	23	30	30	30
Nyctanthes arbor-tristis	26	25	27	27	28	24	24	24	24
Dillenia indica	27	28	23	21	21	21	20	19	22
Dalbergia sissoo	28	27	26	30	30	29	22	21	20
Gmelina arborea	29	29	29	26	25	28	28	28	27
Aegle marmelous	30	30	30	29	29	30	31	31	31
Bridelia retusa	31	31	31	31	31	31	26	26	28

Evaluation of effects of carbon on plant species ranking

The ranking of species based on mix criteria showed 3 different types of circumstances. They are: a. species having same rank based either on excluding or including carbon b. promotion of rank of the plant species and c. demotion of rank of the species (Table 4).

Species having same rank based either on excluding or including carbon

The prioritization of species based on mix rank showed no any differences for some species in these forests. They were altogether 7 in Banke - Maraha CFM, 8 in Tuteshwarnath CFM and 17 species in Gadhanta - Bardibash CFM. The contributions of carbon of these total species were 67.14, 89.65 and 89.31% in Banke- Maraha, Tuteshwarnath and Gadhanta - Bardibash CFM respectively. Explicitly, the most common species were *Shorea robusta*, *Terminalia tomentosa*, *Anogeisus latifolia* , *Lagerstroemia parviflora* and *Eugenia jambolana*.

Promotion of rank

Some species have promoted their rank based on mix than carbon such as *Dalbergia latifolia*, *Schleichera trijuga, Croton roxburghii* and *Acacia catechu*. Total numbers of promoted species were 11 in both Tuteshwarnath and Gadhanta - Bardibash CFMs which was

12 in Banke - Maraha CFM. They were contributed nearly 16.91, 5.72 and 6.14% carbon in Banke - Maraha, Tuteshwarnath and Gadhanta - Bardibash CFMs respectively. Specifically, *Dalbergia latifolia* was prioritized to 10 under mix ranking which was ranked 11 under carbon ranking in Banke - Marha CFM. Similarly, ranking of same species was placed to 14 under mix ranking from 15 under carbon ranking in Tuteshwarnath CFM and lastly it switched to 16 from 17 in Gadhanta - Bardibash CFM. Moreover, *Schleichera trijuga* was climbed to rank 21 under mix ranking from 28 under carbon ranking in Banke - Maraha. Interestingly, *Croton roxburghii* was also promoted the rank to 16 under mix ranking from 19 under carbon ranking in Tuteshwarnath CFM. In case of *Acacia catechu,* this was shifted to 15 under mix from 16 under carbon in Banke - Marha CFM and ranked to 24 from 26 in Tuteshwarnath CFM.

Demotion of species rank

On the other hand the ranks of some species were recorded decreasing place under mix ranking compared to carbon ranking. They were *Eucalyptus camaldulensis*, *Dillenia indica*, *Dalbergia sissoo*, *Alstonia scholaris* and *Nyctanthes arbor-tristis*. Total rank demoted species were 5 in Gadhanta - Bardibash CFM and 10 in both Banke - Maraha and Tuteshwarnath CFMs. The contributions of carbon of these species were 15.96% in Banke - Maraha CFM, 4.63% in Tuteshwarnath CFM and 5.55% in Gadhanta - Bardibash CFM. Mainly, i. *Dalbergia sissoo* was demoted to 28 under mix ranking from 26 under carbon ranking in Banke -Marha CFM. This species was stepped down to 22 under mix ranking from 20 under carbon ranking in Gadhanta- Bardibash CFM and ii. *Eucalyptus camaldulensis* demoted to 18 under mix ranking from 14 under carbon ranking in Banke - Marha CFM, 23 from 20 in Tuteshwarnath CFM and 15 from 13 in Gadhanta - Bardibash CFM.

Table 4. Effect of carbon on ranking based on mix criteria (IVI+ Carbon)

Category	Details	Banke - Maraha	Tuteshwarnath	Gadhanta - Bardibash
Unaffected spp.	N	7	8	17
	% carbon contribution	67.14	89.65	89.31
Promoted spp.	N	12	11	11
	% carbon contribution	16.91	5.72	5.14
Demoted spp.	N	10	10	5
	% carbon contribution	15.96	4.63	5.55

Conclusions

Dominant carbon stocks were found in *Shorea robusta* and *Terminalia tomentosa* but they were very low in *Dillenia indica* and *Eucalyotus camaldulensis*. The species wise carbon stocks were not significantly differed except in *Lagerstroemia parviflora*.

The ranking based on IVI only did not completely represent the value of plant species. So, other criterion was proposed based on mix (IVI + carbon) ranking. This showed promotion of ranking 11 to 12 species in these collaborative forests.

The ranking of species based on mix should be tested for other types of forests too so that its performance can be evaluated confidently.

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References

[1] M. Scherer-Lorenzen, C. Potvin, J. Koricheva, B. Schmid, A. Hector, Z. Bornik, G. Reynolds, E.D. Schulze, *The design of experimental tree plantations for functional 834 biodiversity research. Forest Diversity and Function. Temperate and Boreal Systems*, **Ecological Studies, 176**, 2005, Springer, pp. 347–376.
[2] R.K. Kathryn, P. Catherine, *Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project*, **Forest Ecology and Management 246**, 2007, pp. 208–221.
[3] R.H. Grove, **Green imperialism. Colonial expansion, tropical island Edens and the origins of environmentalism, 1600–1860**, Cambridge University Press, Cambridge, United Kingdom, (2)/ 1995.
[4] E. Gómez-Baggethun, R.D. Groot, P.L. Lomas, C. Montes, *The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes*, **Ecological Economics, 69**, 2009, pp.1209-1218.
[5] R.K. Turner, G.C. Daily, *The Ecosystem Services Framework and Natural Capital Conservation*, **Environment Resource Economics, 39**, 2008, pp. 25–35.
[6] B. Fisher, R.K. Turner, P. Morling, *Defining and classifying ecosystem services for decision making*, **Ecological Economics, 68**, 2009 , pp. 643–653.
[7] D. Pimentel, *Environmental Quality and Natural Biota*, **BioScience, 30**(11), 1980, pp. 750–755.
[8] * * *, **State of the World's Forests**, Food and Agriculture Organization of the United Nations, Rome, Italy, 2011, pp. 201.
[9] * * *, **Tarai Forests of Nepal (2010 - 2012)**, Babarmahal, Kathmandu (pp. 160). Forest Resource Assessment Nepal Project/Department of Forest Research and Survey (4)/2014.
[10] O.E. Sala, F.S. Chapin III, J.J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L.F. Huenneke, R.B. Jackson, A. Kinzig, R. Leemans, D.M. Lodge, H.A. Mooney, M. Oesterheld, N.I. Poff, M.T. Sykes, B.H. Walker, M. Walker, D.H. Wall, *Global biodiversity scenarios for the year 2100*, **Science, 287**, 2000, pp. 1770–1774.
[11] * * *, **World Population Prospects, the 2010 Revision**, United Nations Department of Economic and Social Affairs, 2011.
[12] * * *, **The State of Food Insecurity in the World 2011**, Food and Agriculture Organization. Rome, Italy, 2011 http://www.fao.org/docrep/013/i1683e/i1683e.pdf
[13] * * *, **Human Development Report 2013**, The Rise of the South: Human Progress in a Diverse World. United Nations Development Programme, 2013.
[14] * * *, **Nepal National Biodiversity Strategy and Action Plan**, Ministry of Forests and Soil Conservation, Singhadurbar, Kathmandu, (1)/2014.
[15] A. Karsenty, S. Ongolo, *Can "fragile states" decide to reduce their deforestation? The inappropriate use of the theory of incentives with respect to the REDD mechanism.* **Forest Policy and Economics**18, 2012, pp. 1–52
[16] J.C. Milder, S. J. Scherr, C. Bracer, *Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries*, **Ecology and Society 15**(2), 2010, pp. 4.
[17] K.G. MacDicken, **A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects**, vol. 3, Winrock International Institute for Agricultural Development. Arlington VA (US), 1997.
[18] S.D. Moore, G.P. McCabe, **Introduction to the Practice of Statistics**, vol. 3, M.H. Freeman and Company, New York, Prude University, 2003.
[19] J. Chave, C. Andalo, C. Brown, *Tree allometry and improved estimation of carbon stocks and balance in tropical forests*, **Oecologia, 145**(2), 2005, pp. 87-99.

[20] * * * **IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme**, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds) IGES, Japan. (2)/2006, p. 232.

[21] D.R. Dangol, G.P. Shivakoti, *Species composition and dominance of plant communities in western Chitwan, Nepal*, **Journal of Science and Technology 3**, 2001, pp. 69-78.

[22] G.M. Devagiri, S. Hubballi, G. Pujar, M.S.R. Murthy, S. Trivedi, B. Debnath, Mapping *and Characterization of Bio-rich Areas Using Satellite Remote Sensing in Southern Karnataka, India*, **International Journal of Environmental Sciences, 2,** 2012, pp. 105-117.

[23] J. Meng, Y. Lu, G. Liu, *Structure and floristics of tropicalforests and their implications for restoration of degraded forests of China's Hainan Island*, **International Society for Tropical Ecology. 52**(2), 2011, pp. 177-191.

[24] * * *, **Tarai Forests of Nepal 2010-2012. Forest Resource Assessment**, vol. 1. Nepal Project/Department of Forest Research and Survey, Babarmahal, Kathmandu Forest Resource Assessment, 2014, p. 13.

[25] M.D.S. Chandran, G.R. Rao, K.V. Gururaja, T.V. Ramchandra, *Ecology of the Swampy Relic Forestsmof Kathalekhan from Central Western Ghat India*, **Bioremediation, Biodiversity and Bioavailability. Global Science Books**. Energy and Wetland Research Group, Centre for Ecological Sciences. Indian Institute of Sciences Bangalore 560012 India, **1**, 2010, p.36.

[26] O.P. Chaubey, *Eco-silviculture Options for Sustainable Forest Management in Joint Forest management - A case study of Mixed Forests of Madhya Pradesh of India*, **International Journal of Bioscience and Biotechnology, 4**(1), 2012, pp. 1-16.

[27] B. Adhikari, S.D. Falco, J.C. Lovett, *Household characteristics and forest dependency: evidence from common property forest management in Nepal*, **Ecological Economics, 48**, 2003, pp. 245–257.

[28] I. Pandya, H. Salvi, O. Chahar, N. Vaghela, *Quantative Analysis on Carbon Storage of 25 Valuable Tree Species of Gujrat*, Incredible India. **Indian Journal of Science Resource, 4(**1), 2013, pp.137-141.

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