Article

Comparison of carbon stock in agroforestry systems between two ecological regions of Nepal

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Abstract
Nepal is an agrarian economy-based country where more than 70% of people are still living in the countryside and exercising various types of agroforestry system for a long time. Carbon sequestration through agroforestry system is an emerging strategy to cope with the immediate and long-term impacts of climate change. Having widespread agroforestry systems, the reporting on carbon conservation in this system is very limited. In this context, the study aimed to analyze the carbon stock in the agroforestry system and compare in two different ecological regions of Province 5, Nepal. Home gardens were taken as a reference for the study from Terai (Kapilbastu district) and Mid-hills (Arghakhanchi district) regions. The data were collected in 50 Mid-hills and 30 Terai households through simple random sampling. The appropriate analysis and statistical tests were employed. The result found that the average total biomass was significantly greater ($p<0.05$) in Terai (21.314 t ha^{-1}) than in Mid-hills (11.203 t ha^{-1})).The soil organic carbon (SOC) was found 61.17 t ha^{-1} in Terai and 67.608 t ha^{-1} in Mid-hills, and bulk density found 1.38 g cm^{-3} in Terai and 1.076 g cm^{-3} in Mid-hills region. However, there was no significant difference ($p>0.05$) found in the total carbon stock (biomass and soil) between two ecological regions, indicating that similar amount of carbon is conserving irrespective of ecological regions in the home garden of Province 5, Nepal. However, results suggest that home garden would be a significant viable source of the carbon sink in the terrestrial ecosystem. The results would give insights for multi-purpose agroforestry system management including carbon conservation without jeopardizing food security (agriculture production system) under the same land resources.

Keywords biomass; home garden; Mid-hills; soil organic carbon; Terai.

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1 Introduction

The World Agroforestry Centre defines the agroforestry as a dynamic, ecologically-based natural resource management system that, through the integration of trees in farms and the landscape, diversifies and sustains smallholder production for increased social, economic and environmental benefits for land users at all levels, grounded on the ethnobotanical knowledge, and regarded as a multidisciplinary science (Leakey et al., 1999). Agroforestry system provides ecosystem services, environmental benefits, and economic commodities as part of a multifunctional working landscape (Jose, 2009). In the light of climate change mitigation, carbon storage in both living biomass and the soil is a key ecosystem service provided by forests and agroforests (De Beenhouwer et al., 2016). Agroforestry systems are believed to have a higher potential to sequester carbon than pastures or field crops (Pokhrel and Yadav, 2013). Agricultural lands can sequester 0.85-0.9 Pg C per year; biomass croplands sequester 0.5-0.80 Pg C per year and the forests can sequester 1-3 Pg C per year (Albrecht and Kandji, 2003).

Agroforestry is uniquely suited to provide eco-agriculture solutions that successfully combine objectives for increased food security and biodiversity conservation gains, especially by promoting greater use of native tree species in agroforestry systems (Khanal, 2011). In Nepal, the farming system is integrated with crop production, animal and tree husbandry. Trees on farmland contributed fuelwood for cooking and fodder to the livestock, fruit as a source of food. In addition to this, trees play an important role in the preparation of local medicine and soil conservation. Nutrients for cropland come from animal manure and leaf material (Regmi, 2003). Due to the rapid deforestation and change in the ownership and management of the forest, people are seeking new alternatives and one of such alternatives is agroforestry involving both indigenous and exotic fodder tree species in private farmlands (Neupane et al., 2002). Moreover, agroforestry offers an economic opportunity for subsistence farmers in developing countries like Nepal for selling the carbon sequestered through agroforestry to industrialized countries (Pokhrel and Yadav, 2013) as carbon trade and such other mechanism such as clean development mechanism (CDM).

Several studies are in place in forest ecosystem (e.g., Pandey and Bhusal, 2016; Pandey et al., 2019) and very few studies in agroforestry carbon conservation in Nepal (Neupane et al., 2002; Pokhrel and Yadhav, 2013; Amatya et al., 2018). The site-specific information and understandings are key for resolving ecological, environmental and societal challenges. Realizing these facts, this study aimed to analyze and compare the carbon sequestration in agroforestry systems especially in the home garden maintained in two different ecological regions namely Terai and Mid-hills of Province 5 of Nepal. The result would give insights for multi-purpose agroforestry system management including carbon conservation without jeopardizing food security (agriculture system) under the same land resources utilization.

2 Study Area and Methodology

2.1 Study site

The study area included the Bahigaon village of Chhatradev Rural Municipality and Bodgaon village of Banganga Municipality of Arghakhanchi and Kapilbastu districts from Mid-hills and Terai region of Central Nepal respectively (Fig 1). These Municipalities were selected based on a good number of home gardens practices and their utilization compared with the other Municipalities of the regions. Moreover, the research is conducted voluntarily as easiness for researchers for data collection is another reason for selecting those sites.

The field visit was conducted in October- November 2019 (one month) because the season is gloomy and having the leafy vegetation to identify the plants easily. Also, people gather for a festival reason to get support in data collection and the home-garden is filled with the crops.

The study area is presented in Fig 1.

2.1.1 Chhatradev Rural Municipality

Chhatradev Rural Municipality is located at North-East belt of Arghakhanchi district which falls in Mid-hills region of Nepal. Major ethnic groups inhabiting in the area were *Brahmin*, *Chhetri*, *Magar*, *Newar*, *Kami*, *Damai* and *Sarki*. Major vegetation includes; *Schima wallichii*, *Castanopsis indica*, *Myrica esculenta*, *Alnus nepalensis*, *Madhuca longifolia* in and around the study site. The Rural Municipality experiences the subtropical type of climate. From 1981 to 2010, the highest average maximum temperature was 30.6^{0}C and the lowest average minimum temperature was 7.1^{0}C while, the highest average rainfall was 940.3 mm in July (DHM, 2016).

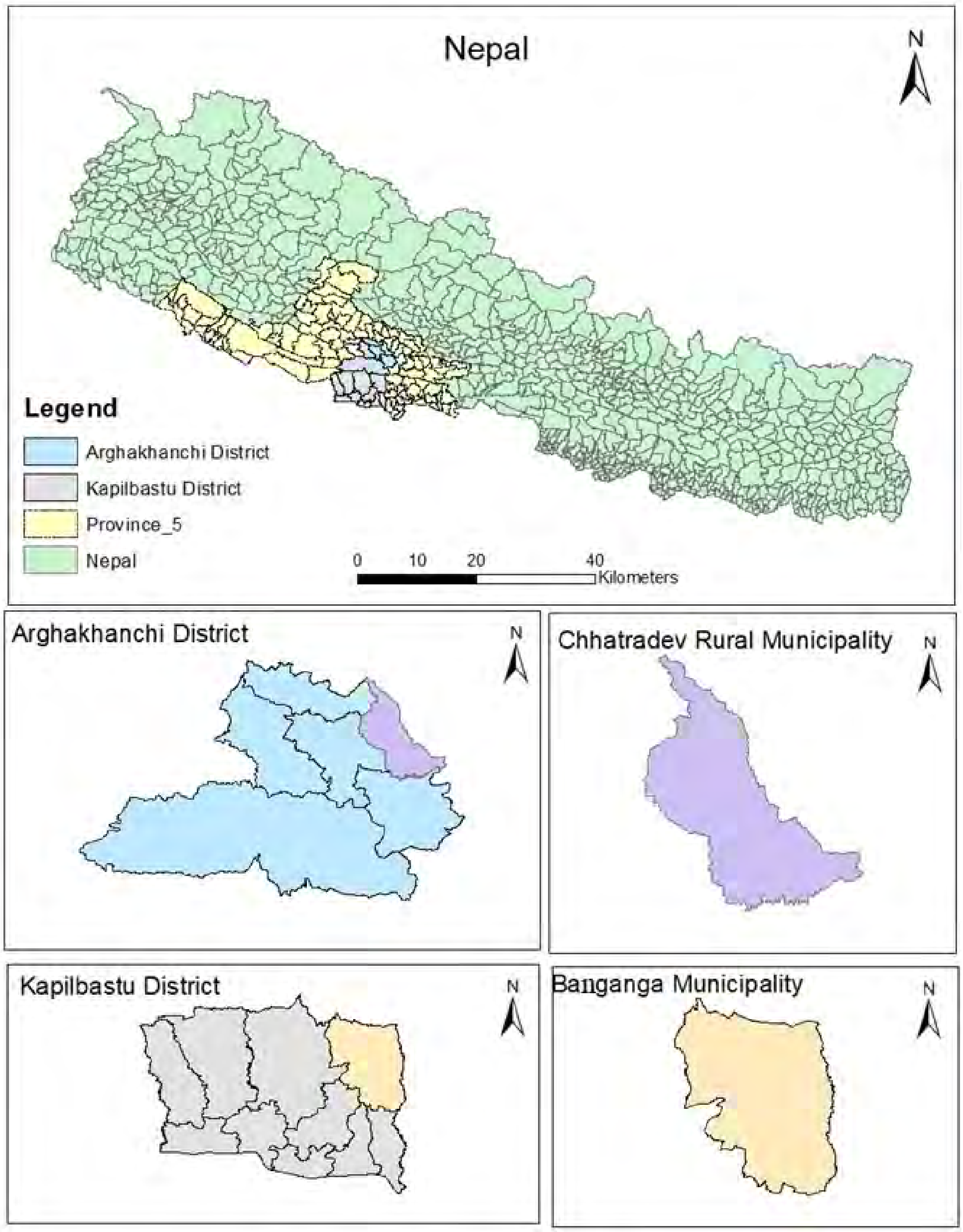

Fig. 1 A map showing the study area (Top: Map of Nepal and an indication of the study area; Middle left: Arghakhanchi district; Middle right: Chatradev Rural Municipality; Bottom left: Kapilbastu district; Bottom right: Banganga Municipality).

2.1.2 Banganga Municipality

The Banganga Municipality is located at North-East belt of Kapilbastu district which falls in Terai region of

Nepal. Major ethnic groups residing in the area are *Brahmin*, *Chettri*, *Gurung*, *Magar* and *Tharu*. The vegetation of the area was dominated by *Dalbergia sissoo, Shorea robusta, Leucaena leucocephala, Artocarpus lakoocha.* The area experiences the hot and humid climate during the summer and cold during the winter. For the period of 1981-2010, the highest average maximum temperature was 36.4^{0}C and the lowest average minimum temperature was 8.8^{0}C while, the highest average rainfall was 545.6 mm in the month of July (DHM, 2016).

2.2 Materials and methods

2.2.1 Sampling design

Random sampling was done to cover the study about the home garden and species composition. Thirty (50) households out of 200 households and fifty (30) households out of 150 households were taken from Mid-hills and Terai region, respectively for the study. Households were selected randomly for socio-economic data collection and vegetation analysis.

2.2.2 Data collection

A participatory data collection and plant identification approach was followed for both districts. Within each household information related to home garden and species, the composition was collected through complete enumeration of that household. The plant species were identified by the structured and unstructured questionnaire and direct field observation. A structured questionnaire survey was also used to collect qualitative information from the home garden users. The plant species grown in the home garden, irrigated land and non-irrigated lands owned by farmers for multiple purposes were listed out and cross-validated with the help of the responses provided by the respondents.

2.3 Data analysis

2.3.1 Biomass Carbon Analysis

Plots of the quadrat size 20 m × 20 m were set in and around the home garden of each household. The number of trees inside the plots was listed with the help of the information given by the respondents. The girth measuring tape was used to measure the girth at breast height (1.30 m from the ground level) of the individual trees inside the plot and later converted it to its diameter (DBH) equivalent using the equation;

$$\textit{Diameter (cm)} = \textit{circumference (cm)}/\pi.\ \textit{where}\ \pi = 3.1416 \text{ (Labata et al., 2012).}$$

The biomass was estimated by using allometric equation models developed by Chave et al. (2005) as below.

$$\text{Above-ground biomass (AGB)} = 0.0509 \times \rho\ (DBH)^2 H$$

where ρ = wood specific gravity (g/cm^3); *DBH* is expressed in cm; *H*= height of the plants in meters. The value of ρ was obtained from the secondary data source of Zanne et al. (2009). But, the above-ground biomass (AGB) of plants with DBH< 10 cm (called sapling) were estimated using a global equation given by Zianis (2008). The equation is as follows: -

$$AGB = a\ (DBH)^b$$

where a=0.1424 and b=2.3679.

Above-ground biomass tons per hectare (t ha^{-1}) was calculated as:

$$AGB = \frac{Sum\ of\ AGB\ of\ the\ plot\ \times\ 100\ \times\ 100}{20\ \times 20} \times \frac{1}{1000}$$

The root-shoot ratio was used to estimate below ground biomass (BGB) as an inventory could calculate root biomass as not less than 10 or 15% of above-ground biomass (MacDicken, 1997).

$$BGB = AGB \times 0.15$$

Below ground biomass tons per hectare (t/ha) was calculated as:-

$$BGB = \frac{Sum\ of\ BGB\ of\ the\ plot \times 100 \times 100}{20 \times 20} \times \frac{1}{1000}$$

The carbon stock in living biomass ($C.S_B$) was estimated by multiplying the sum of dry biomass (i.e. T.B=AGB+BGB) by 0.47 which is the default carbon fraction in dry biomass as suggested by IPCC (2006).

$$C.S_B = T.B \times 0.47\ kg$$

Finally, the carbon stock in the biomass was converted into tons per hectare (t ha^{-1}) as follow:

$$Carbon\ stock\ in\ biomass = \frac{Sum\ of\ biomass\ carbon\ stock\ of\ the\ plot \times 100 \times 100}{20 \times 20} \times \frac{1}{1000}$$

2.3.2 Soil organic carbon analysis

To analyze the soil organic carbon (SOC), soil samples were collected from 30cm depth at almost about the centre of the quadrat with the help of digger. The soil samples were collected from each household of study sites i.e. 30 samples from the Terai region and 50 samples from Mid-hill samples. The soil samples from Terai were mixed in a single bulk and similarly, the soil samples from Mid-hills were also mixed in another single bulk. The soil samples were air-dried separately for one week in shade and stored in airtight zipper plastic bags. Samples of soil were brought to Nepal Agriculture Research Council (NARC), Lalitpur for further analysis of various parameters to determine carbon stock in the soil. Walkey and Black's rapid titration method was referred to estimate the soil organic carbon of the soil samples.

The soil carbon stock was estimated by applying the relation given by Winrock International as REDD (Reducing Emissions from Deforestation and Forest Degradation) Methodological Module (2009). The relation was given as:

$$C_{SOCsp,i,t=0} = C_{SOCsample,sp,i,t=0} \times BD_{sample,sp,i,t=0} \times Dep_{sample,sp,i,t=0} \times 100$$

where $C_{SOCsp,i,t=0}$=Carbon stock in soil organic carbon for sample plot *sp*, stratum *i*, at time *t*=0; *t C* ha^{-1}; $C_{SOCsample,sp,i,t=0}$= oil organic carbon of the sample in sample plot *sp*, stratum *i*, at time *t*=0; determined in the laboratory in g C/100 g soil (fine fraction <2 mm); $BD_{sample,sp,i,t=0}$= Bulk density of fine (<2 mm) fraction of mineral soil in sample plot sp, Stratum *i*, at time *t =0*; determined in the laboratory in g fine fraction cm^{-3} total sample volume; $Dep_{sample,sp,i,t=0}$ = Depth to which soil sample is collected in sample plot in stratum *i* at time *t*=0; *sp* = 1, 2, 3 … *Pi* sample plots in stratum *i*, *i* = 1, 2, 3 … *M* strata; *t*=0, 0 years elapsed since the start of the project activity.

2.3.3 Soil bulk density analysis

The bulk density was determined as described as;

$$\text{Bulk density} = \frac{\text{Mass of the soil(g)}}{\text{The volume of soil(cm}^3\text{)}}$$

2.3.4 Total carbon stock

The total carbon stock of the sampled plots was ultimately calculated by summing up the carbon stock due to biomass and carbon stock due to the soil.

$$\text{Total carbon stock (t ha}^{-1}) = \text{Carbon stock in biomass (t ha}^{-1}) + \text{Carbon stock in soil (t ha}^{-1})$$

2.4 Statistical analysis

All data were subjected to the test of normality. Mann-Whitney U-test was used for the comparison of mean and Pearson correlation was performed to correlate the variables. Linear regression was carried out to observe the pattern between the variables. MS Excel and R (R Core Team, 2018) were used for the statistical analysis. The relevant data were analyzed and presented in their respective forms inferential and descriptive statistics.

3 Results and Discussion

3.1 Basic characteristics of study sites

The mean, sample size and standard deviation measurement of various parameters is given in Table 1. Most of the values were significantly higher in the Terai region. In the case of the diameter of trees and soil, organic carbon stocks were significantly higher in Mid-hills region while there was no significant difference found between the total carbon stocks of two ecological regions in studied sites. The biomass carbon stock, soil carbon stock and the total carbon stock are shown in Fig 3.

Table 1 Parameters of studied sites in two ecological regions.

Parameters	Terai (**mean ± sd**)	Mid-hill (**mean ± sd**)
Diameter at breast height(cm)	14.91 ± 8.69 *(n= 248)*	17.1853 ± 7.81 *(n= 228)*
Tree height(m)	7.13 ± 3.3316 *(n= 248)*	6.54 ± 3.618 *(n= 228)*
Basal Area(m^2ha^{-1})	4.788 ± 3.188 *(n= 30)*	3.1725 ± 1.819 *(n= 50)*
Tree stem volume(m^3 ha^{-1})	23.95 ± 1.98 *(n= 30)*	13.574 ± 1.26 *(n= 50)*
Above ground biomass(t ha^{-1})	18.97 ± 1.506 *(n= 30)*	9.741 ± 9.415 *(n= 50)*
Below ground biomass(t ha^{-1})	2.745 ± 2.306 *(n= 30)*	1.456 ± 1.411 *(n= 50)*
Total biomass(t ha^{-1})	21.0502 ± 1.76 *(n= 30)*	11.1603±1.082 *(n= 50)*
Total biomass carbon stock (t ha^{-1})	10.255 ± 8.14 *(n= 30)*	5.24 ± 5.0874 *(n= 50)*
Soil bulk density(g cm^{-3})	1.38 ± 0.107 *(n= 30)*	1.076 ± 0.11062 *(n= 50)*
Soil carbon stock (t ha^{-1})	61.17 ± 15.808 *(n= 30)*	67.608 ± 10.121 *(n= 50)*
Total carbon stock (t ha^{-1})	71.433 ± 18.38 *(n= 30)*	72.856 ± 11.098 *(n= 50)*

3.2 DBH-class distribution of trees

The DBH distribution of trees from the study area is presented in Fig 2.

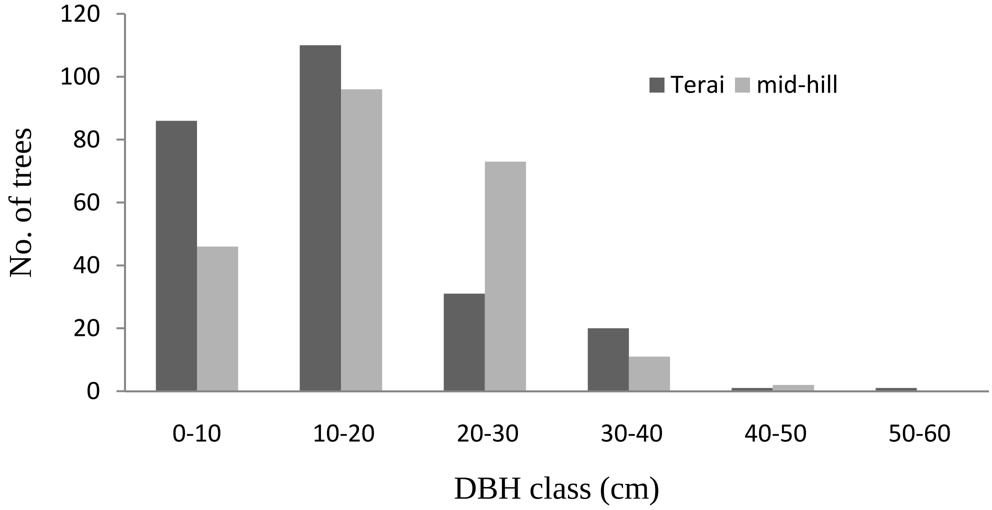

Fig. 2 DBH distribution of tree species in the study area.

Result found that the plants with DBH<10cm were more frequent in the Terai region than Mid-hills (Fig. 2). The number of plants with DBH 20-30 cm was more than double in the Mid-hills region than the Terai region. However, the plant's frequency with higher DBH (>30 cm) was almost similar in both regions. Thus, this has resulted in higher mean DBH in the Mid-hills region (Fig. 2). This result showed that the people in the Terai region were willing to grow small-habit trees but higher in frequency than those of Mid-hills people. Further, in the Mid-hill, most of the plants were used for the fodder and timber purpose which are naturally thicker than the other trees contributing to larger average DBH in Mid-hills region.

3.3 Total carbon stock

The biomass carbon stocks, soil carbon stock, and cumulative carbon stock from the study sites are presented graphically (Fig. 3).

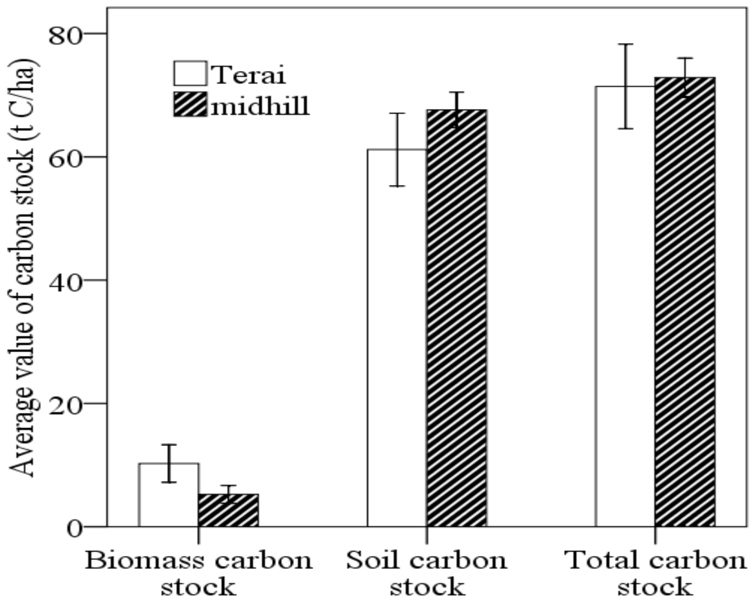

Fig. 3 Carbon stock in biomass and carbon stock in soil and the total carbon stock in the sampled plots of Terai and Mid-hill regions. Columns represent average values with vertical bars as the standard error of the mean.

Result found that the soil carbon stock was higher in Mid-hills than in the Terai.On contrary to this the biomass carbon in Mid-hills is quite lesser than that of the Terai region. The result found that the average total biomass was significantly greater (p<0.05) in Terai (21.314 t ha^{-1}) than in Mid-hills (11.203 t ha^{-1}) (Table 1). The mean of total biomass carbon stock was found to be 10.255 t ha^{-1} and 5.24 t ha^{-1} for Terai and Mid-hill respectively (Table 1; Fig. 3). The soil carbon stock was found 61.17 t ha^{-1} in Terai and 67.608 t ha^{-1} in Mid-hills (Table 1; Fig. 3) whose bulk density found 1.38 g cm^{-3} in Terai and 1.076 g cm^{-3} in Mid-hills region (Table 1). However, there was no significant difference (p>0.05) found in the total carbon stock (biomass and soil) between two ecological regions i.e. 71.433 t ha^{-1} in Terai and 72.856 t ha^{-1} in Mid-hills (Table 1; Fig. 3).

Similar observations of differences in carbon densities in various research find because of various factors associated with the systems. The variation on the carbon density is mainly due to environmental factors (Pandey et al., 2020a), variation in nutrient availability especially primary nutrients (NPK) in the areas (Pandey et al., 2020b) and anthropogenic disturbances (Pandey, 2020). The latter case is the most prevalent in the agroforestry system where artificialism is the dominant factor. The average of total carbon stock in the present study was comparable to the finding in the tropical agroforestry system which ranged from 12- 228 Mg ha^{-1} (Albrecht and Kandji, 2003). The finding was however 1.2 times less than the Falcata - coffee multistory system in Bukidnon, Philippines (Labata et al., 2012) and 3.75 times less than the Karahiya community forest of Rupandehi district, Nepal (Shrish, 2012). Also, the mean carbon stock was 1.48 times less than the mean carbon stock of home-garden in Indonesia (Roshetko et al., 2002). The finding was 1.3 times greater than the soil organic carbon stock in the farm with trees in Kanchanpur district, Nepal (Baral et al., 2013) under a similar land-use system.

In the Terai region, there is higher temperature and humid condition which is considered a favourable situation for the metabolism of micro-organisms. There was higher litterfall and also the rate of decomposition was higher in Terai due to which the amount of carbon is in biomass not in soil. While, in Mid-hill, the temperature and soil conditions were less favourable for the micro-organisms as compared to Terai as a result the dead matters take much time to be decomposed and ultimately much of the carbon remains in the soil but not up took as biomass. However, long term carbon conservation in any system including agroforestry requires sustainable management of the system (Pandey, 2011).

3.4 Correlation analysis

The Pearson correlation test was performed to see whether the parameters were interrelated or not (Zhang and Li, 2015). The test result revealed the relationship between the various parameters in both regions. The relationship is shown in Table 2.

Table 2 Pearson correlation test result between parameters understudy.

Parameters	Correlation coefficient (Mid-hills)	Correlation coefficient (Terai)
DBH- Total height	0.611	0.717
Basal area - Above ground biomass	0.891	0.942
Basal Area-Total Biomass	0.892	0.883
Soil Bulk Density - Soil Organic Carbon	0.667	0.620
Biomass Carbon Stock - Soil Organic Carbon	-0.50	0.085

The result suggests that agroforestry system could be multi-purpose ecological system management in changing context. The highest Pearson's correlation is seen between the basal area and above-ground biomass in case of Terai region whereas the lowest correlation is found between biomass carbon stock and soil organic carbon stocks for the same region. However, a negative correlation is found in the case of biomass carbon stock and soil organic carbon stock for the Mid-hills region. This case may be the result of higher temperature and humid condition which is considered a favourable situation for the metabolism of micro-organisms in Terai and was higher litterfall and also the rate of decomposition was higher in Terai due to which a large amount of carbon released is stored in biomass, not in soil. While, in Mid-hill, the temperature and soil conditions were less favourable for the micro-organisms as compared to Terai as a result the dead matters take much time to be decomposed and ultimately much of the carbon remains in the soil but not up took as biomass, thus the test resulted in negative correlation.

4 Conclusions

The study concludes soil has a larger capacity to store organic carbon than the vegetation that grows in the agroforestry system. Also, higher biomass contents in Terai's home garden has lower carbon constituent in the soil whereas the result is just opposite in Mid-hills region where a higher amount of soil carbon grows the lesser amount of tree biomass in the farmers' home garden in two different ecological regions of Province 5 Nepal. In conclusion, the agroforestry systems especially home gardens are similar in terms of the amount of carbon conservation based on the ecological region under study. However, as results suggested, the agroforestry can store a large amount of carbon from the atmosphere and could be a viable strategy under the global climatic problem. In these study areas, people are exercising different mode of agroforestry system for their daily livelihood activities. Carbon sequestration through agroforestry system is an emerging strategy to cope with the immediate and long-term impacts of climate change in all its coping options such as adaptation, mitigation and resilience. The results suggest that a significant amount of carbon can be conserved in the agroforestry system without jeopardizing food security - agriculture production.

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References

Albrecht A, Kandji S. 2003. Carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems and Environment, 99: 15-27

Amatya SM, Cedamon E, Nuberg I. 2018. Agroforestry Systems and Practices in Nepal (Revised Edition). Agriculture and Forestry University, Rampur, Nepal

Anonymous. 2009. Estimation of carbon stocks in the soil organic carbon pool. Winrock International, USA

Baral SK, Malla R, Khanal S, et al. 2013. Trees on farms: diversity, carbon pool and contribution to rural livelihoods in Kanchanpur district of Nepal. BankoJanakari, 3(1): 3-11

Beenhouwera MD, Geeraerta L, Mertensa J, et al. 2016. Biodiversity and carbon storage co-benefits of coffee agroforestry across a gradient of increasing management intensity in the SW Ethiopian highlands. Agriculture, Ecosystems and Environment, 222: 193-199

Chave J, Andalo C, Brown S, et al. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145(1): 87-99

http://verra.org/wp-content/uploads/2017/11/VMD0004PublicComment.pdf

Jose S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems, 76(1): 1-10

KalabaKF, Chirwa P, Syampungani S, et al. 2010.Contribution of agroforestry to biodiversity and livelihoods improvement in rural communities of Southern African regions. Environmental Science and Engineering, 461-476

Khanal S. 2011. Contribution of agroforestry in biodiversity conservation and rural needs fulfilment. Master's Thesis to the Tribhuvan University-Institute of Forestry, Nepal

Khanal Y, Sharma RP, Upadhyaya CP. 2010. Soil and vegetation carbon pools in two community forests of Palpa District, Nepal. BankoJanakari, 20(2): 34-40

Labata MM, Aranico EC, Tabaranza ACE, et al. 2012. Carbon stock assessment of three selected agroforestry systems in Bukidnon, Philippines. Advances in Environmental Sciences, 4(1): 5-11

Leakey RRB, Martin GJ, Agama AL. 1999. The evolution of agroforestry systems. Cultivating Trees, 5

MacDicken KG. 1997. A Guide To Monitoring Carbon Storage In Forestry and Agroforestry Projects. Winrock International Institute for Agricultural Development, USA

Neupane RP, Sharma KR, Thapa GB. 2002. Adoption of agroforestry in the hills of Nepal: A logistic regression analysis. Agricultural Systems, 72: 177-196

Omoro L, Starr M, Pellikka PK. 2013. Tree biomass and soil carbon stocks in indigenous forests in comparison to plantations of exotic species in the Taita Hills of Kenya. Silva Fennica, 47(2): 1-18

Pandey HP, Bhusal M. 2016. A comparative study of carbon stock in two different ecological regions of Nepal. BankoJanakari, 26: 24-31

Pandey HP, Pandey P, Pokhrel S, Mandal RA. 2019. Relationship between soil properties and forests carbon: Case of three community forest from Far Western Nepal. BankoJanakari, 29(1): 43-52

Pandey HP, Paudel G, Pokhrel S, Pokhrel N. 2020a. Response of Environmental Variables and Carbon Enhancement in Community Forests, Nepal. International Journal of Ecology and Environmental Sciences, 2(3): 22-29

Pandey HP, Pokhrel S, Pandey P, Pokhrel N, Paudel G. 2020b. Effect of primary nutrients (NPK) on forests biomass production and SOC density of Nepalese forests. Proceedings of the International Academy of Ecology and Environmental Sciences, 10(3): 86-96

Pandey HP. 2020. A participatory anthropogenic disturbances analysis response to diversity, recruitment and carbon density in forests of Nepal. Journal of Resources and Ecology

Pandey HP. 2011. Conservation and management of forests may be conflicting: How can we best combine conservation and utilization within the same geographic area? The Prabhat, 16: 167-173

Pokhrel CP, Sharma S, Yadav RKP. 2013. Agroforestry and ecosystem services. International Journal of Science Innovations and Discoveries, 3(1)

Powlson DS, Whitmore AP, Goulding, KWT. 2011. Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. European Journal of Soil Science. 62: 42-55

REDD Methodological Module “Estimation of carbon stocks in the soil organic carbon pool” Version 1.0 - April 2009

Regmi BN. 2003. Contribution of agroforestry for rural livelihoods: A case of Dhading District, Nepal. In International Conference on Rural Livelihoods, Forests and Biodiversity, 19-23

Roshetko JM, Delaney M, Hairiah K, et al. 2002. Carbon stocks in Indonesian home garden systems: can the smallholder system be targeted for increased carbon storage? American Journal of Alternative Agriculture, 17(2): 138-148

Shrestha K. 1998. Dictionary of Nepalese Plant Names. Mandala Book Print, Kantipath, Kathmandu, Nepal

Shrish O. 2012. Carbon stock of selected tree species of Karahiya community forest, Kapilbastu District, Nepal. MSc Dissertation, Central Department of Botany, Tribhuvan University, Kathmandu, Nepal

Sunwar S. 2003. Home gardens in Province 5 Nepal: opportunities and challenges for on-farm management of agrobiodiversity. MSc Thesis, Uppsala University, Sweden

Vitousek PM, Sanford RL. 1986. Nutrient cycling in the moist tropical forest. Annual Review of Ecology and Systematics, 17: 137-167

Zanne AE, Lopez-Gonzalez G, Coomes DA, et al. 2009. Global wood density database. Dryadidentifier. http://Hdl.Handle.Net/10255/Dryad.235

Zhang WJ, Li X. 2015. Linear correlation analysis in finding interactions: Half of predicted interactions are undeterministic and one-third of candidate direct interactions are missed. Selforganizology, 2(3): 39-45

Zianis D. 2008. Predicting mean aboveground forest biomass and its associated variance. Forest Ecology and Management, 256(6): 1400-1407.

Zobel DB, Jha PK, Behan MJ, et al. 1987. A Practical Manual for Ecology. RatnaPustak Distribution, Kathmandu, Nepal