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Survey on Tree Carbon Stock inside Mahendra Multiple Campus, Nepalgunj, Banke

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Abstract

Carbon stock in plant bodies is the significantly longer period reservoir for the atmospheric CO_2 that causes adverse impacts on living and non-living climatic and environmental factors while increasing its proportional concentration in air. The present study aimed to estimate the carbon stock in trees of Mahendra Multiple Campus territory. The study was carried out by purposive sampling method, where altogether ten plots were laid of size 8.92m radii and measured diameter at breast height (DBH) (1.3m) and angle of inclination was taken from 5m horizontal distance from the tree pole. The calculation was made following the equation given by Chave et al., 2005 for wet forests. In total 17 species of trees were reported with the dominant species *Dalbergia sissoo* followed by *Corymbia citriodora* based on DBH and population density. The total carbon stored by trees inside the territory of MMC, Nepalgunj was 76.44 tons per hectare which is approximately 1/3rd of the world's tropical forest average carbon stock. It implies the importance of trees outside the forest in carbon sequestration and balancing carbon emissions. Further estimation of carbon dioxide emitted from the territory, by different carbon emitters inside the area is recommended.

Keywords: Carbon Stock, *Dalbergia sissoo*, Sequestration, Trees Outside Forest (TOF)

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Introduction

Carbon stock also known as carbon pool is a structure that can store carbon in different forms/pools other than the atmosphere (FAO, 2010). Carbon stock in plant bodies is a significantly longer period reservoir for the atmospheric CO_2 that causes adverse impacts on living and non-living climatic and environmental factors while increasing its proportional concentration in air. CO_2 are essential component but hazardous when reaches its optimum level. It reduces both carbon assimilation and functioning in plants. Such assimilated carbon remains stored for several decades inside the perennial tree poles and helps to balance carbon concentration in the atmosphere. Such carbon inside the tree is known as tree carbon stock.

Modernization and urbanization are the major causes of carbon discharges in the environment these days, that have changed the proportional concentration of carbon dioxide in air and its compounds. Increasing carbon dioxide concentrations have shown adverse impact on climate, air, soil, water, human health as well, as plant and animal community (Dawud et al., 2016). One of the more appropriate and longer-period carbon sinks are perennial plants, mainly tree habits, that store carbon dioxide from the atmosphere in their body by the process of photosynthesis and regulate the far-going food chains as a biochemical process (KC et al., 2016).

Unmanaged industries, huge use of vehicles, chemical uses, overpopulation, and burning of fossil fuels are the major sources of carbon emission in the environment (Aryal et al., 2013). Additionally, global socio-economic scenarios are changing and giving rise to the more prevalent problems of deforestation, land use change, and global climate change (KC et al., 2016; Khadka et al., 2019). Addressing these problems, biological carbon sequestration by plants comes at the forefront as they are the only living beings with the ability to sequestrate atmospheric carbon in the organic compound form in their shoots, and roots for a longer time and contribute to checking carbon proportion in the air (KC et al., 2016).

About 40 to 50 percent dry biomass of trees is known as carbon (Madpuri et al., 2021). Carbon is stored in carbon reservoirs like forests, leaf litter, undergrowth plants, sediment, and rocks are the carbon sources that also make the function of forests. (Olorunfemi et al., 2019; Liu et al., 2019; Poudel et al., 2020). Carbon stock is affected by different factors, including the type of forest, age of forest density, and density of trees (Aryal et al., 2013; Pandey et al., 2014). Thus, forests are the major reservoir of carbon, however, trees outside the forest such as in private gardens, children's parks, commercial areas, government offices, and greens along the road also contribute to storing carbon emissions (Schnell et al., 2015; Chakravarty et al., 2019).

Trees that grow outside the forests and provide services like regular forests but are not included in forest monitoring and measurement programs; and are named trees outside the Forests (TOF) by the Food and Agriculture (FAO) in the middle of the 90s' (Bellefontaine et al., 2002; Baral et al., 2013; Shrestha et al., 2020). The carbon emission and pollution level has frequently been tried to alleviate by the growth of trees outside the forest, however, the carbon stock in those trees were rarely been estimated and evaluated for the purpose aim. It is important to estimate and analyze if the trees growing outside the forest are playing a role in carbon sequestration. The main objective is to calculate the total tree carbon stock inside the garden of Mahendra Multiple Campus Nepalgunj.

Literature Review

There are different categories of forests government, community, religious, private, protected, and leasehold forests are found in Nepal (Acharya, 2002). The government-managed and protected forests are managed at the direct government level with the help of different government bodies whereas community, leasehold, and religious forests are managed by local communities, and private forests are managed by individual households (Singh and Chapagain, 2006). Forest-based carbon sequestration is no permanent as there is a significant risk of carbon reversal.

Tropical home garden agroforestry system has come with potential carbon sequestration ability along with significant contribution to biomass production, soil carbon nutrient ratio, climate change impacts mitigation, and biodiversity enhancement (Islam et al., 2015). From the literature reviewed on trees outside the forest and trees inside the forest, there is an established fact that trees are major carbon sinks in a biological perspective. Small patches of trees are also crucial in a regional scale to absorb and alleviate carbon in atmosphere. In case of Nepal, Forest covers 5.96 million ha i.e., 40.36% of the total area of the country. And the total forest living biomass in Nepal is 485 million metric tons (above-ground 359 million metric tons and 126 million metric tons by below-ground biomass) (FAO,2010).

A total of 186.95 t/ha of carbon stock density was found in the *Shorea robusta* forest in the community forest of Palpa district Nepal (Nepal, 2006) whereas Shrestha (2008) reported that 235.95t/ha carbon stock density in *Shorea robusta* forest of hilly region. The total carbon stock of the *Shorea robusta forest* was higher than the pine forest than pine forest (Baral et al. 2009). The carbon sequestration rate was dependent on the growing nature of the forest stand by different forests. The disintegration of organic carbon is determined by the different climatic factors like temperature and moisture which vary with altitudinal variation (Amundson, 2001).

The Global Forest Resources Assessment Report of FAO (2010) reported that the value of average carbon stock density was lower than the carbon stock density in the forest of Nepal (161.1t ha-1). The total carbon stock of the Nepalese forest has been estimated at 1,054.97 million tons (176.95t/ha). To this total carbon stock tree components, soil and litter, and debris contribute 61.53%, 37.80%, and 0.67% of stocks respectively (DFRS, 2015). An increasing proportion of different hazardous elements like carbon dioxide due to the changing living attitudes of humans brought changes in the ecosystem and biogeochemical cycles. Biological carbon sequestration helps to maintain the ratio of free carbon dioxide gases in the atmosphere and serves as a carbon sink. Researchers are now in search of appropriate tree species with higher carbon storage ability for the community forest plantations in cities (Aryal et al., 2013).

A recent study carried out in the Kathmandu metropolitan city has also revealed the significant amount of carbon sequestration by planted trees of Pine and Eucalyptus with a potential impact on the global carbon cycle (Sharma et al., 2020). Carbon stock of trees outside forests (TOF) carried out in Tanahun district revealed the socioeconomic and environmental importance of those trees (Bhandari et al., 2021). Such small patches of trees when considered at a community or regional level, contribute significantly to the national carbon budget depending on the household number, area, and species (Bhandari et al., 2021). It has also been proved by the research work carried out in the Indonesian home garden system for both livelihood and carbon storage with appropriate tree species and management policies (Roshetko et al., 2000).

The community-managed forest had higher carbon stock in comparison to the adjacent government forest showing the significance of forest management systems on carbon stock improvement (Mbaabu et al., 2014; Aryal et al., 2018). Forest/trees grown in the gardens could be a representative of such a management system contributing to global carbon sequestration on a small scale. However, such plantations in every organization of cities might bring some significant impact. Previous studies have shown higher tree carbon storage in a pine-dominated forest than in a mixed forest of a mid-hill city area (Aryal et al., 2013). Furthermore, different researchers have carried out similar studies on the carbon stock of trees outside the forest showing their importance (Yadav et al., 2017).

From various aspects, trees outside the forests play an important role in alleviating some level of carbon from the atmosphere. Most of the land cover is now changing and getting fragmented which deteriorates the area of the green part. For this shifting of land module and utility, there is an urgent need for a concept regarding trees outside the forest which promotes both greenery and carbon sequestration in the urban areas.

Research Methodology

Study Area

The study of Carbon stocking of the tree was done inside the boundary of Mahendra Multiple Campus Nepalgunj. The study area lies at 81°37'E and 28°03'N at an elevation of 150m above sea level (asl) (Subedi et al., 2022). The total area of the study area is 115,134.71m^2 and mixed forests were dominated by *Dalbergia sissoo* and *Corymbia citriodora*. The average annual precipitation is about 1100mm with four dry months; thus, a small patch of trees here has been considered a moist tropical forest and the allometric equation has been selected on the same basis.

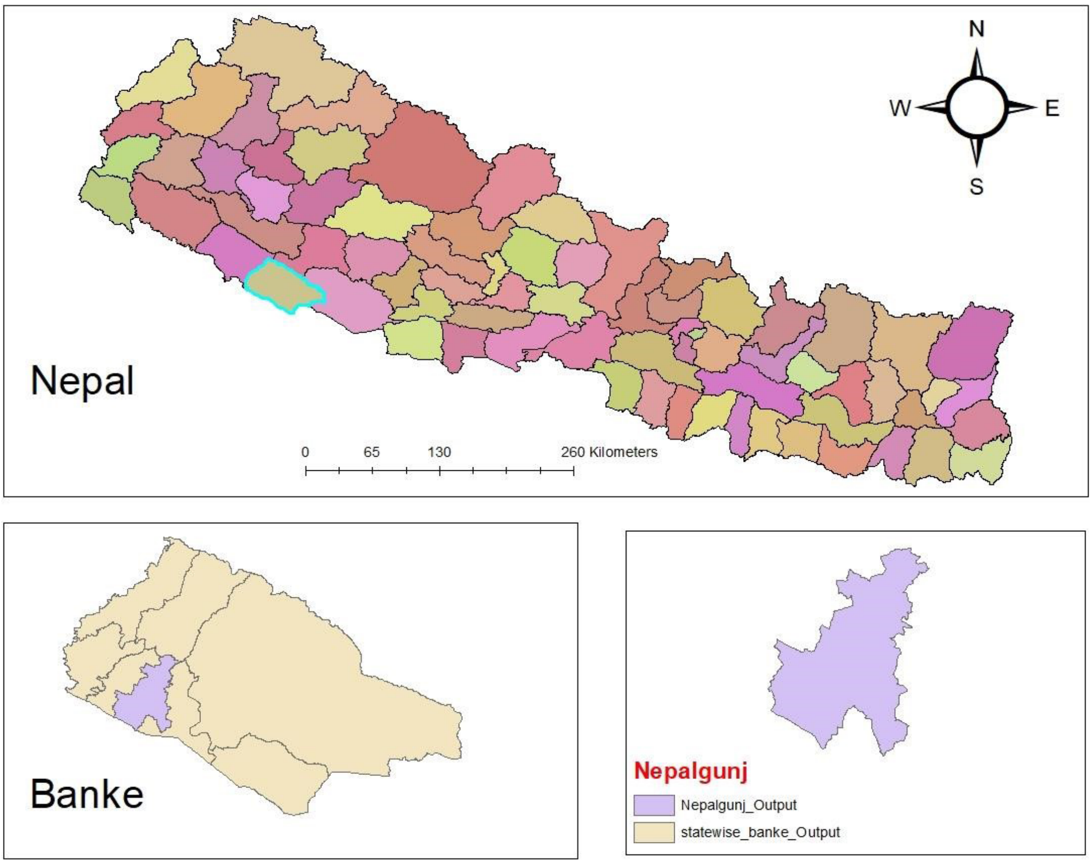

Figure 1: Map of Study Area showing location of Campus

Data collection and analysis

Trees satisfying standard diameter (DBH) for the tree category (i.e., >10cm) was selected and measured for the carbon stock (Chave et al., 2005). All three sites of the campus area with trees will be counted and measured. All the tree pole height was measured using a clinometer and meter tape. Further calculations were made using Pythagoras' theorem in MS excel 2010. Similarly, the Diameter at Breast Height (DBH) was measured using DBH tape at the height of 1.3m from the ground level (Chave et al., 2005). The allometric model equation for the calculation of above-ground biomass, below-ground biomass, and carbon stock given by Chave et al., (2005) was followed for the moist forest as equations 1, 2, 3 & 4:

Above Ground Biomass (AGB) (kg) = $0.0509\times \rho D^2 H$ ……………………….(1)

Where, ρ is the specific wood density (g/cm^3),

D is the diameter of a tree at breast height(cm) and H is the height of a tree (m)

Above Ground Carbon Stock (AGCS) = AGB×0.47……………………….(2)

Below ground carbon stock (BGCS) = AGCS×0.24 ……………………….(3)

Total carbon stock (TCS) = AGCS + BGCS ……………………………….(4)

Specific wood densities of corresponding species were used as given in a standard list of specific wood densities for tropical plants (Reyes et al., 1992).

Complete analysis and presentation of results were prepared in MS Excel 2010. Results were presented in tabulated form and graphs.

Regarding the standard format of ICIMOD Nepal, their guidelines are for carbon stock estimation of forest and agroforest ecosystems not for the trees outside the forest (ANSAB, 2010; Karki et al., 2014). Also, that implies sampling and measurement optimum for large-scale estimation in larger areas. Thus, several sampling and measured variables are lesser than those mentioned in the guidelines.

Results and Discussions

Tree species richness

The present study revealed altogether 17 species of trees belonging to 16 genera under seven angiosperm families (Annex 1). Among 17 species reported from the area, most of the individuals belong to the family Fabaceae followed by Myrtaceae. These families have well-known distribution along the tropical region. The individual from other taxa were also present but in small numbers which might be due to their lower rate of reproductive ability, mode of reproduction, seed viability, seed dormancy, seed dispersal, and germination frequency than that of Fabaceae.

Measurements of tree species

Measured tree poles for their carbon stock showed the variation in their height and DBH, consequently, carbon storage in their poles. Tree height ranged from 3.42 to 25.12 m and tree trunk diameter at breast height ranged from 6.0 to 67.0 cm (Table 1). The longest tree was of *Dalbergia sissoo* and largest one was of *Ficus benjamina* locally known as sisso and Pakhari/Shamee. Whereas shortest tree was of *Leucaena leucocephala* and *Sesbania sesban* locally known as *babul* / *ipilipi* and *jaita* respectively. The carbon stock is estimated based on plant height, DBH and density which differ along the species and individual (Thuille & Schulze 2006; Aryal et al., 2013). Variations in the tree height, DBH, biomass, and ultimately their carbon stock might be due to their natural habit of small to large longer surviving trees with different ages and seasonal variation faced by individual plant throughout their life (ANSAB, 2010; Pandey et al., 2014).

Table 1: Height and DBH range for different tree species in MMC territory

S.N.	Name of species	Height (m)		Diameter at Breast Height (cm)	
		Maximum	Minimum	Maximum	Minimum
1	Azadirachta indica A.Juss.	20.26	4.49	55.0	18.0
2	Bauhinia purpurea L.	6.60	5.80	23.4	11.0
3	Bauhinia variegata L.	10.26	5.10	47.5	8.0
4	Callistemon citrinus (Curtis) Skeels	8.74		12.2	12.2
5	Cassia fistula L.	6.60	5.80	27.0	22.0
6	Corymbia citriodora (Hook.) K.D.Hill & L.A.S.Johnson	20.26	6.60	57.5	13.7
7	Dalbergia sissoo Roxb. ex DC.	25.12	5.10	50.0	6.0
8	Ficus benjamina L.	10.26		67.0	
9	Leucaena leucocephala (Lam.) de Wit	3.93	3.42	13.0	11.0
10	Plumeria rubra L.	7.56		22.0	
11	Saraca asoca (Roxb.) W.J.de Wilde	8.74	5.10	51.2	23.0
12	Schleichera oleosa (Lour.) Oken	17.95		35.0	
13	Senegalia catechu (L.f.) P.J.H.Hurter & Mabb	6.60	6.10	14.0	12.0
14	Sesbania sesban (L.) Merr.	3.93	3.42	11.0	10.0
15	Syzygium cumini (L.) Skeels	12.32	8.74	32.0	19.0
16	Tectona grandis L.f.	7.56		16.0	
17	Vachellia farnesiana (L.) Wight & Arn.	4.49	3.72	13.0	10.5

Tree Pole biomass above ground

Similarly, the correlation plot drawn AGB against DBH shows the positive co-relationship between DBH and above ground biomass (Figure 2). On increasing the DBH, the biomass has been also increased (R2 = 0.72). It shows an exponential relation where, each species of trees has increasing above-ground biomass with increasing DBH. It is most obvious that the increased size of living tree trunk might have higher biomass as the DBH represents the growth status of plants and their overall biomass accumulation (Baral et al., 2009; Aryal et al., 2018). Further, studies also show similar variations in tree DBH and height, and consequently, the biomass of different tree species depending on tree age, species, environmental condition, soil, and climatic factors (Pandey et al., 2014).

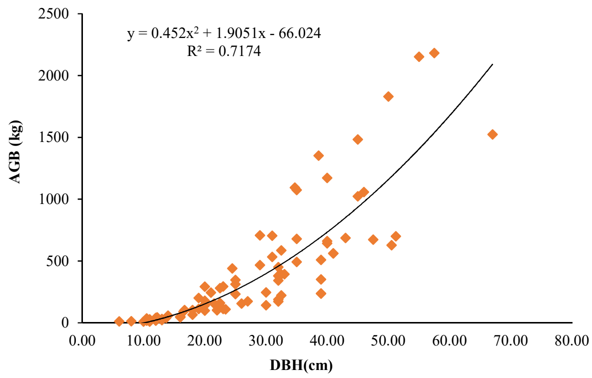

Figure 2: Above-ground biomass along the DBH of tree species

Carbon Stock of tree poles

Furthermore, the total tree carbon stock of the sampled area was 76.42 tons per hectare of which 66.47 tons were above ground and 9.97 tons were below ground carbon stock (Table 2). It is approximately 1/3rd of tropical forest average carbon stock in the world i.e., 285.0 tons/ha (Pandey et al., 2014). It implies that nearly three official territories with trees can have as much carbon storage as a tropical forest of Nepal.

More interestingly, the total area of campus territory is about 11.5 ha, whereas if all the area is covered by a similar type of forest composition, it may hold about 879.05 tons of carbon. It is more than 3 folds of the world's tropical forest average carbon stock. Thus, a small number of trees inside the territory of organizations and private land also plays an important role as a carbon sink (Pain-Orcet and Bellefontaine, 2004).

Table 2: Carbon Stock of tree species in Mahendra Multiple Campus territory

TAGB	TAGB (Kg/m^2)	TAGB (t/ha)	TAGC	TBGC	TCS	*TCS of campus area
35356.04	14.14242	141.4242	66.46936	9.970404	76.43976	879.0572

(Note: TAGB: Total Above Ground Biomass; TAGC: Total Above Ground Carbon; TBGC: Total Below Ground Carbon; TCS: Total Carbon Stock; *If entire area covered by similar forest composition)

Carbon stock is a major factor estimated in different parts of the world for the air monitoring and management of carbon emissions by different regions in the world by preparing biological carbon sinks. These sinks are now exchanged and monetized for economic enhancement and as a substitute for carbon emission by larger companies, industries, and research centers that emit carbon in the atmosphere. The major carbon sink in the biological aspect is tropical forests in the different parts of the world (Bredin et al., 2020). Present work from the tropical region of Nepal showed the probability of carbon management via tree plantation outside the forest.

Conclusion

Plants are major biological carbon sink that stores atmospheric carbon and trees from the outside area of the forest are also found to be an important pool. The present study simply shows the carbon assimilation by trees outside the forest, contributing to the world's carbon sequestration. Thus, further detailed estimation of carbon emission from such small organization and their carbon stock by the trees may help to initiate a new concept of carbon management or storage within self-territory.

Recommendations

Trees outside the forests should be promoted and appropriate tree species for the area based on available space, carbon storage ability and life span of trees with possibly multiple benefits must be recommended. The recommendation should be given with priority to native species that are more significant to our native biodiversity promotion and their conservation.

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