Plant Archives Vol. 26, Supplement 1, 2026 pp. 528-534 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.071

BIOMASS AND CARBON SINK POTENTIAL OF DIFFERENT TREE SPECIES IN KHADAR SOIL OF PRAYAGRAJ, INDIA

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(Date of Receiving : 06-08-2025; Date of Acceptance : 04-11-2025)

ABSTRACT

In this research paper, Carbon Sink Potential in different tree species after 15 years of planting in Khadar soil (Jamuna alluvial) was carried out. In the present study, it is revealed that plant incremental attributes viz., Mean Annual Increment (MAI), Above-Ground Biomass (AGB) Below Ground Biomass (BGB), and total biomass of tree species have significant variations among all tree species. *D. sissoo* was found the highest Mean annual Increment (MAI) at diameter as well as the highest Mean annual increment at height among all trees of research. Total biomass was found a maximum 30.16 q/tree in *D. sissoo* and 16.66 q/tree in *E. globulus* respectively. The qualitative growth of *Azadirachta indica* and *A. lebbeck* was found poor as they adduced less average biomass in Khaddar soil (Jamuna alluvial) in Prayagraj region. The total carbon sink potential of the different tree species was estimated highest (235.24 t/ha) in *D. sissoo* and *E. globulus* (129.94 t/ha), *Delonix regia* (33.85 t/ha) respectively.
Keywords **:** Carbon sink potential, Biomass, mean annual increment and Khadar Soil etc.

Introduction

Trees play a crucial role in mitigating the diverse impacts of environmental carbon degradation and in reducing global warming (Mishra *et al.*, 2019). They facilitate carbon sink potential into soil and plant biomass, making tree-based land use practices viable alternatives for storing atmospheric carbon dioxide (Mishra *et al.*, 2020). These practices are cost-effective, exhibit high potential for carbon uptake, and offer associated environmental and social benefits (Dhruw *et al.*, 2008). However, large-scale deforestation, which has reached 5.2 million hectares in the past decade (FAO 2020), has significantly impaired the carbon sequestration capacity of the biosphere (Keeling and Khorf 2002). Furthermore, the release of carbon from the consumption and burning of fossil fuels by power industries has led to a considerable increase in atmospheric carbon levels (Mishra *et al.*, 2022). To mitigate global warming, it is legally imperative to reduce carbon emissions or to enhance carbon storage in terrestrial ecosystems (Shrinivas and Sundarapandian, 2019).

Forests, which maintain over 86% of the terrestrial carbon sink potential, play a significant role in this process by photosynthesizing and capturing excess carbon as total biomass in the topography. Accurate estimates of forest carbon storage, including that of natural forests, plantations, and grasslands across various localities, are of great significance for research on terrestrial ecosystem productivity, the carbon cycle, and global warming.

The annual global Carbon Budget projects fossil carbon dioxide (CO_2) emissions of 36.8 billion tonnes in 2023, up 1.1 % from 2022 (Global Carbon Budget Report 2023). The report projects that total global CO_2 emissions (fossil + land use change) will be 40.9 billion tonnes in 2023 (Global Carbon Budget Report 2023).

Generally, predictions of the sequestration rate of different tree species cannot be evaluated, since growth and sequestration depend on factors of locality viz., climatic condition, topographic condition, and edaphic features however, the rate of carbon sink potential depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood (Yin *et al.*, 2012).

Over the last 20 years, several researches focusing on the carbon sink potential, carbon density, and carbon soring of forest ecosystems have been done by many countries (Liu and Fang, 2000). khadar soil and al occupies 71.48 percent of Uttar Pradesh state and 10 percent in Prayagraj district (KVK Prayagraj, 2024) is categorized as wasteland because it only supports pastures due to nutrient deficiencies and adverse physical properties. After tedious efforts, only a few tree species survive in Prayagraj. In the present study, 15-year-old tree plantations were selected to assess the intensity and rate of biomass and carbon sequestration by different species with various objectives of evaluating the potential tree species for Prayagraj region (khadar soil) revitalization.

Materials and Methods

Site Profile

The District Prayagraj (Sangam Nagri) is situated in Southern Eastern part of the state Uttar Pradesh however, it lies between the parallel of 24^0 and 47' North latitude and 81^0 19' East longitude Prayagraj is demarcated on the eastern side by district Bhadohi (Sant Ravidasnagar) North side by district Jaunpur and Pratapgarh Western side by District Kaushambi and Chitrakoot. South Eastern corner by district Mirzapur and the southern side by district Rewa Madhya Pradesh state from north to south breath is 109 km and from east to west plan is 117 km. (KVK Prayagraj, 2024). The total geographical area of the district is 5437.2 sq. km. The river Ganga and the Jamuna divides Prayagraj into three distinct regions namely Gangapar Jamunapar and Dwaba the Gangapar and Jamunapar is the city of the Allahabad district where Dwaba area comes under district Kaushambi (KVK Prayagraj, 2024).

Study Site

The research was conducted in the roadside plantation of Prayagraj (Sangam Nagri) a district in Uttar Pradesh's south-eastern region, India. The study focused on different roadside plantations in Prayagraj sites viz. Company Garden, Minto Park, P.D Tandon Park, Hathi Park, Arail Road, CSFER, AU.

To understand how carbon sequestration patterns vary among plantation types, the carbon stock in eight roadside plantations using non-destructive method (Mishra *et al.*, 2022). The research was carried out on the roadside tree species during 2019-20 which can understand the atmospheric pressure on the different tree species by biotic and abiotic elements.

Species & plot Descriptions

The road side plantations covered nearly 100 ha with different tree species viz., Kala siris (*Albizia lebbeck*), Neem (*Azadirachta indica*), Shisham (*Dalbergia sissoo*), Nilgiri (*Eucalyptus globulus*), Aonla (*Emblica officinalis*), Arjun (*Terminalia arjuna*), Pipal (*Ficus religiosa*) and Gulmohar (*Delonix regia*) species in spacing of plant to plant 4 x 4 m distance accommodating 625 plants in a hectare. After a socioeconomic and primary survey of the entire site, trees were enumerated according to diameter at breast height (1.37 m) in 50 x 50 m sample plots. A total of 100 trees were considered for each species to determine DBH (diameter at breast height) and height and divided with the different ages of tree species for the calculation of Mean Annual Increment of Diameter and Height by using measuring tape and Ravi Altimeter respectively. The following formulas were considered for study evaluation.

Methodology

Above-ground biomass (AGB) is calculated by two methods as its calculation depends on the taxonomic characteristics of different tree species.

1. This formula is considered for the tree has shorter crown/ canopy expansion area or the trees have straight bole/stem.

   Volume of the tree was calculated by the formula, $V = \pi r^2 H$ (Mishra *et al.*, 2020).

Where, V= volume of the tree in m^3, r= radius of the trunk in m, H = Height of the tree. Above ground biomass is calculated by multiplying between the volume of trees and wood density.

$$AGB = V \times D$$ (Mishra *et al.*, 2019).

Where, AGB= Above Ground Biomass, V= Volume of the tree in M^3 and D= Wood Density of species (Mishra *et al.*, 2022).

Wood density is used from the global wood density database which was published by Forest Research Institute (FRI 2006). The standard average density of 0.6 g/cm^3 is applied wherever the density value is not available for tree species.

2. This formula is considered for the tree has a broader crown/ canopy expansion area

For the AGB, the regression model recommended by Chave *et al*. (2005) was used since it is a result of critical validation of an extensive dataset collected at sites ranging from dry humid tree canopy to semi-humid tree closed canopy. The formula is used as following

$$AGB\ trees/shrubs = 0.112 \times \rho D^2 H^{0.916}$$

Below Ground Biomass (BGB) has been calculated by the multiplying the AGB by 0.26 (Hangarge *et al.*, 2012).

$$BGB = AGB \times 0.26$$

Total Biomass (TB) was calculated by the addition of total of Above Ground Biomass and Below Ground Biomass (Mishra *et al.*, 2022).

$$Total\ Biomass = AGB + BGB$$

In the present study, we have calculated carbon with the assumption, that any tree species contains 50% of its biomass (Pearson *et al.*, 2005).

$$Carbon\ Storage = Biomass \times 50\%$$

Carbon Density- The biomass C contents were then summed and divided by the area of the plot to give AGB and BGB carbon density values for the area expressed in Mg C ha^{-1} (Mishra *et al.*, 2022).

Carbon sequestration (CO_2e)- The elemental carbon removed from the atmosphere (CO_2) was then calculated as per procedure followed by Drury *et al.* (2002).

$$CO_{2e} = C_b \times 3.67$$

(To convert C → CO_2, multiply by ratio of molecular weights (44g CO_2/mol) to (12g C/mol)

Carbon Sink potential is calculated by multiplying by total carbon storage into 3.67.

Statistical analysis

The statistical analysis was carried out using SPSS version 23.0 for the calculation and interpretation of the data. To see the relationship between response variables (mean diameter, mean height, volume, biomass, carbon stock, and CO_2 stocks) and the predictor variables for roadside plantations was employed to measure the correlation between these variables. Regression analysis was also run to test the relationship between average mean height and carbon sink potential.

Result and Discussion

Table-1 shows mean annual increment of diameter and height were significantly varied among tree species in khadar soil. The mean annual increment concerning the diameter maximum found in *Dalbergia sissoo* and *Eucalyptus globulus* was 1.754 cm/year and 1.731 cm/ year respectively, however, the lowest in *F. religiosa* with 0.613 cm/year (Mishra *et al.*, 2019). The highest MAI height was 0.913 m/ year found in *Dalbergia sissoo* whereas *Eucalyptus globulus had found a minimum* of 0.817 m/year followed by *F. religiosa* with 0.524 cm/year. Wood density was found maximum 0.69 g/ cm^3 in *A. indica* followed by *F. religiosa* (0.68 g/ cm^3). The wood density was recorded lowest in *D. regia* (0.51 g/ cm^3) (Fig.1).

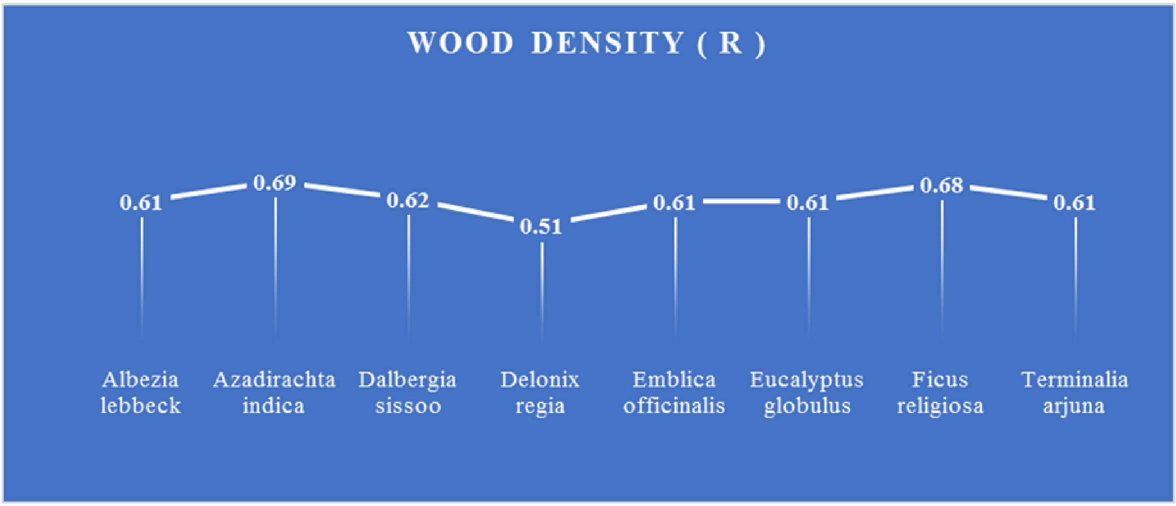

Fig. 1: Wood density of tree species

Table 2 shows Above-ground biomass (AGB) of tree species in khadar soil. It depicted that *Dalbergia sissoo* and *E. globulus* species stored 22.01 q and 12.06 q higher. Above-ground biomass (AGB) depicted by *A. indica* and *A. Lebbeck* were 1.70 q and 1.85 q/tree, which is lowest in the present study (Mishra *et al.*, 2020). *Dalbergia sissoo* and *E. globulus* species accumulated 8.14 q and 4.49 q highest with respect to Below Ground Biomass (BGB) Similarly. However, the Above ground biomass (AGB) depicted by *A. indica* and *A. Lebbeck* were 0.63 q and 0.68 q/tree, which is the lowest in the present research study (Mishra *et al*., 2019). Total biomass accumulation in *Dalbergia sissoo* and *E. globulus* species have the highest at 30.16 q and 16.66 q respectively (Bhardwaj and Chandra 2016). AGB shown by *A. indica* and *A. Lebbeck* were 2.34 q and 2.54 q/tree, which is the lowest in the present investigation. The fast-growing tree species viz. *D. sissoo* and *E. globulus* produced higher biomass than other species as revealed by this study. This was in confirmation of the results of Kaul *et al.*, 2010 who reported the higher annual biomass in *Dalbergia sissoo* and *E. globulus* due to its fast growth and rapid storage of carbon. Similarly, Pandya *et al.*, 2013 also reported variations in carbon storage in different parts of tree species due to varied growth patterns.

Table 1 : MAI of Diameter and height of tree species at 15-year age in khadar soil

Sl. No.	Species	MAI Diameter (cm)	MAI Height (M)
01	Eucalyptus globules	0.712	0.817
02	*Ficus religiosa*	0.613	0.524
03	*Azadirachta indica*	0.782	0.573
04	*Dalbergia sissoo*	1.754	0.913
05	*Terminalia arjuna*	0.789	0.615
06	*Albizia lebbeck*	1.731	0.617
07	*Delonix regia*	1.572	0.642
08	*Emblica officinalis*	0.698	0.654
	CD at p< 0.05	0.051	0.032

Table 2 : Biomass and carbon sink potential of tree species in khadar soil

Sl. No.	Species	AGB (Q/tree)	BGB (Q/tree)	Total Biomass (Q/tree)	Carbon Stock (Q/tree)	Yearly Carbon storage (t/ha)
01	*Eucalyptus globulus*	12.16	4.49	16.66	8.33	20.82
02	*Ficus religiosa*	1.90	0.70	2.61	1.30	4.27
03	*Azadirachta indica*	1.70	0.63	2.34	1.17	3.37
04	*Dalbergia sissoo*	22.01	8.14	30.16	15.08	37.70
05	*Terminalia arjuna*	2.51	0.93	3.45	1.72	4.05
06	*Albezia lebbeck*	1.85	0.68	2.54	1.27	2.54
07	*Delonix regia*	3.16	1.17	4.34	2.17	3.42
08	*Emblica officinalis*	2.27	0.84	3.12	1.56	5.72
	CD p <0.05	0.77	0.18	1.85	0.33	0.45

Table 3 : Accumulation of Biomass, Carbon, and CO_2

Species	Total Biomass (in q)	Total Carbon (in q)	Total Carbon Stocks (in q)
Albezia lebbeck	254	127	464.82
Azadirachta indica	234	117	428.22
Dalbergia sissoo	3016	1508	5519.28
Delonix regia	434	217	794.22
Emblica officinalis	312	156	570.96
Eucalyptus globulus	1666	833	3048.78
Ficus religiosa	261	130.5	477.63
Terminalia arjuna	345	172.5	631.35

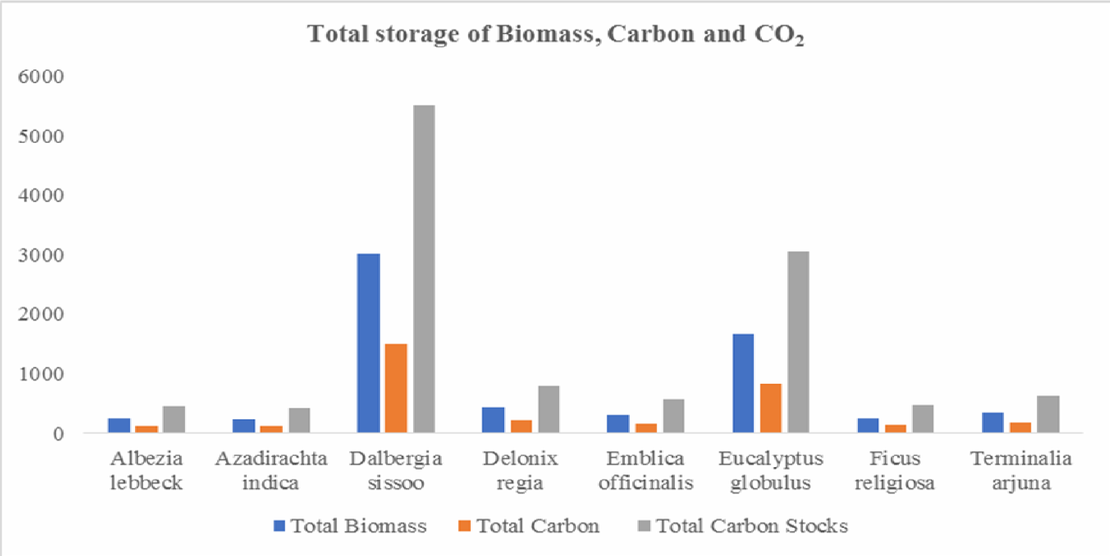

Fig. 2 : Total storage of Biomass, Carbon, and CO_2

Table 4 : Correlation between Mean Diameter, Biomass, Carbon, and CO_2

	Mean Diameter	Biomass	Carbon Storage	Carbon Sequestration
Mean Diameter	1			
Biomass	.385	1		
Carbon Storage	.385	1.000**	1	
Carbon Sequestration	.385	1.000**	1.000**	1

*** Correlation is significant at the 0.01 level (2-tailed).*

Table 5 : Correlation between Mean Height and CO_2

	Carbon Sequestration	Mean Height
Carbon Sequestration	1	.948**
Mean Height	.948**	1

*** Correlation is significant at the 0.01 level (2-tailed).*

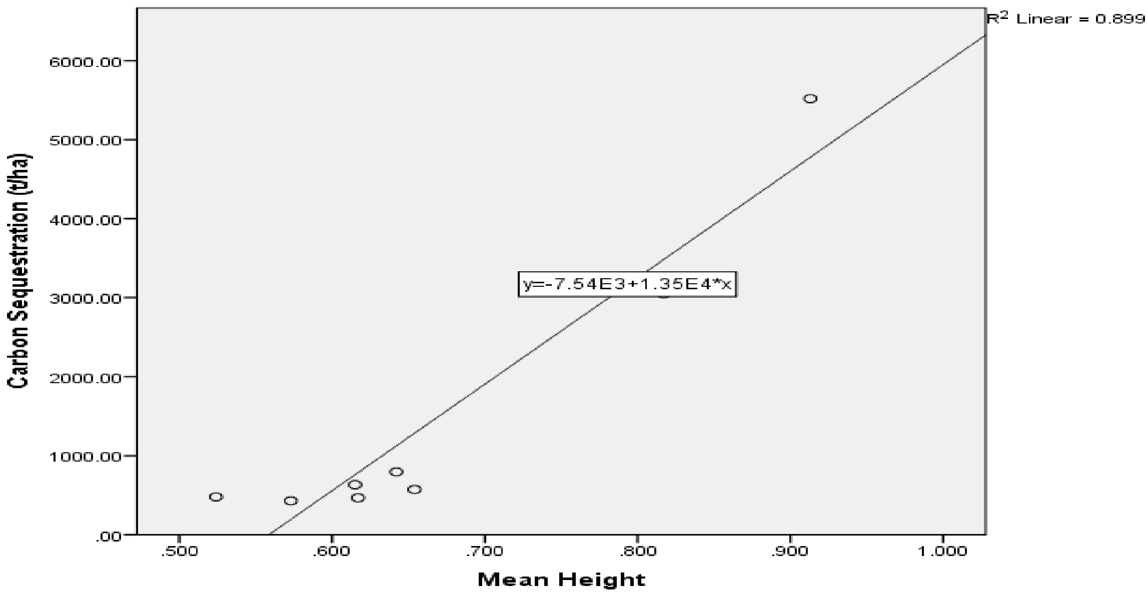

Fig. 3 : Correlation between Mean Height and CO_2

Data on Carbon storage in different tree species is depicted in Tables 4 and Table 5 revealing that Carbon storage strongly correlated with the diameter, height, and biomass of the tree species, and is strongly positive r =, 0.948 and 0.385 (Table 4 and 5). The higher the biomass of the tree species, carbon storage would be more in wood. As in the present study, Biomass of trees varied greatly in Khadar soil of Prayagraj region and only two species namely *Dalbergia sissoo* and *Eucalyptus globulus* exhibited good yearly growth and thereby higher biomass than other species, resulting in the highest carbon storage 15.08 q/tree and 8.33q /tree respectively. Due to higher yearly carbon storage the same attribute. These results concord with the findings of the other workers. Similar results propounded by Sohrabi *et al.* (2016) depict variations in above ground biomass (AGB) and Carbon stocks was comparatively lower in species planted in Khadar soil except for *A. lebbeck* and *E. globulus* (Chaturvedi *et al*., 2011 and Borah *et el*., 2013)

Conclusions

The study revealed species-specific variation in tree volume biomass, and carbon sink potentials across plots in different roadside tree species in Prayagraj. Biomass and carbon sink potentials decreased with narrower spacing compared with that in more widely spaced plantations due to greater intraspecific competition large crowned and long-lived tree species such as *Ficus species* and *Azadirachta indica* may be planted 6-8 m apart, whereas shorter-lived species such as *Dalbergia sissoo* and *Eucalyptus globulus* can be planted 4-5 m apart, In the studied roadside plantations, the abandonment of Fabaceae species led to increased tree volume and biomass, with *Dalbergia sissoo* and Eucalyptus globulus demonstrating the highest carbon sequestration potential, making them ideal for urban roadside plantations aimed at climate change mitigation in cities and developing countries.

Disclosure Statement

The authors declare no competing interest.

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