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A Comparative Study on Carbon Sequestration potential Of Teak Plantations in the interior and exterior Location of Thithimathi Forest

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Abstract

Teak (*Tectona grandis*) is one of the most widely cultivated tropical hardwood species, valued for its durability, versatility, and economic importance. Despite extensive plantation programs across Asia, Africa, and Latin America, limited studies have quantified carbon cycling in teak forests. This study investigates biomass variation and carbon sequestration in teak plantations at interior and roadside locations of the Thithimati forest, India. Using plot-based measurements of tree height and girth, basal area, standing volume, above- and below-ground biomass were estimated, followed by carbon stock and carbon dioxide sequestration calculations. Statistical analyses, including descriptive statistics and independent t-tests, revealed significant differences between the two plantation types. Results showed that interior forest plantations exhibited higher basal area (1.33 m^2), volume (241.40 kg/m^3/ha), total biomass (147,160 kg/ha), and carbon sequestration (73,580 kg/ha) compared to roadside plantations (0.45 m^2, 67.51 kg/m^3/ha, 82,308 kg/ha, and 20,577 kg/ha, respectively). The findings highlight the superior carbon storage potential of interior teak plantations, emphasizing their role in climate change mitigation and sustainable forest management. This study provides quantitative insights into carbon cycling in teak plantations and underscores the importance of site-specific management strategies to maximize ecological and economic benefits.

Introduction

Forests play a critical role in mitigating climate change by acting as major carbon sinks, absorbing atmospheric carbon dioxide and storing it in biomass and soils. Among tropical forest ecosystems, managed plantations have gained increasing attention for their potential contribution to carbon sequestration, particularly in regions where natural forests are under pressure from human activities. Teak (Tectona grandis), one of the most widely planted and economically valuable tropical hardwood species, has been extensively cultivated across Asia, Africa, and Central America. Its durability, high-quality timber, and adaptability to

diverse ecological conditions make it a preferred species for plantation programs. Teak plantations are now being recognized for their role in carbon storage, offering dual benefits of timber production and climate change mitigation.

India has a long history of teak plantation management, dating back to the mid-19th century, with Nilambur in Kerala being one of the earliest sites. Today, teak plantations cover vast areas across the country, including the Kodagu district of Karnataka, where Thithimathi forest is located. The region's tropical climate, fertile soils, and agroforestry practices provide favourable conditions for teak growth. However, variations in site characteristics- such as interior forest locations with dense canopy cover versus exterior forest edges exposed to human activity can significantly influence biomass accumulation and carbon sequestration potential. Understanding these differences is essential for improving plantation management strategies, balancing ecological sustainability with economic returns.

This study aims to compare the carbon sequestration potential of teak plantations situated in the interior and exterior locations of Thithimathi forest. By analysing variations in biomass distribution, soil carbon, and overall carbon cycling, the research seeks to provide insights into how site-specific factors affect carbon storage. The findings will contribute to a better understanding of teak's role in climate change mitigation and inform future plantation management practice that optimize both timber production and environmental benefits. . Keeping these things in view, the present study is planned and executed with following objectives.

1. To study the variation in biomass and carbon stock in interior and exterior locations of Thithimati forest.
2. To compare the biomass and carbon stocks with other related parameters.

Materials and Methods

Data source: For our study we selected Thithimati forest area in which we selected two locations inside and outside forest area.

For collection of data, we laid out three plots of 20X20m in each location and collected height and girth of each individual tree in Teak plantations.

Measurement of tree height and girth

Height and girth at breast height of all trees (girth > 30cm, height>6m) From the measured girth at breast height were converted into diameter at breast height. Mean of all the trees of different species was calculated.

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The calculations made are described as follows.

Basal area

Basal area was calculated using the formula,

Basal area = $d^2/4$, where d is the diameter at breast height of the tree

Volume

Standing volume of tree was calculated using the relation,

Volume of standing trees =Basal area x height x Form factor (0.33)

Biomass

Using the calculated volume of the trees, Above ground tree biomass (AGTB) was calculated using the formula,

AGTB= Volume(m^3) x wood density (kg per m^3)

Wood density for each species was obtained from Global wood density database, ICRAF

Below ground tree biomass (BGTB) was obtained from above ground tree biomass

BGTB (ton ha^{-1}) = AGTB x 0.26 (Ravindranath and Ostwald, 2008)

Total tree biomass was calculated from the addition of above and below ground tree biomass.

Estimation of carbon storage

For any species 45-50% of its biomass is considered as carbon (Personnel *et al.*, 2005).

Carbon storage= biomass x 50%

Estimation weight of carbon dioxide sequestrated in the tree

The atomic weight of Carbon is 12.001115. The atomic weight of Oxygen is 15.9994. The weight of CO_2 is 43.999915. The ratio of CO_2 to C is 43.999915/12.001115=3.6663. Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663 (http://www.ncsec.
org/cadre2/team18_2/students/helpCalcCO2.htm).

Statistical Analysis

The variation in tree biomass, basal area and carbon stock under two conditions was determined by using descriptive statistics and coefficient of variation.

The comparison among tree basal area, biomass and carbon stocks in interior and exterior locations of teak plantations were computed using independent t-test for two samples at 5% level of significance.

Results and Discussion

In the present study, we found the variation in basal area, volume, above ground biomass, below ground biomass, total biomass and carbon sequestration teak plantations in two

locations of Thithimathi forest area. The results are presented in systematic manner as follows, Table 1 variations in carbon sequestration, biomass of teak plantations in two locations. The tree growth parameters girth and height of trees are measured to calculate volume of individual trees and considering volume of individual tree we calculated above ground biomass, below ground biomass and carbon sequestration. For studying variations in carbon sequestration inside and road side of Thithimati forest area we applied descriptive statistics mean, standard deviation, standard error and co-efficient of variation as represented in the Table 1. Co-efficient of variation of basal area of teak plantation inside is more (50.87%) than outside teak tree basal area (24.19%), these indicates compared to road side plantations the inside plantation shows more basal area consistently. for remaining parameters like volume, aboveground and below ground biomass, total biomass and carbon sequestration, the carbon sequestration obtained co-efficient of variation from inside forest area is 51.18 percent is more than outside the forest area (25.09%).

According to the Table 1 we conclude that carbon sequestration is better inside forest area (73580.01kg/ha) than outside (20577.1kg/ha). volume is estimated by using measured parameters from individual trees, and it shows better inside (241.40kg/m^3/ha) the forest area compared to the outside (67.51kg/m^3/ha). The comparison of carbon sequestration (Kg/ha), Total biomass (Kg/ha) and Basal area (m^2) from Teak plantations inside and roadside Thithimathi forest area is clearly shown in the Fig 1, Fig 2 and Fig 3 using Box plots.

The comparison between basal area inside and outside forest area of teak plantation is computed by independent t-test and it clearly indicates the significant difference in basal area between inside and outside the forest area at 5% level of significance (p-value < 0.05). The carbon sequestration between inside and outside forest area is statistically significant (p-value < 0.05) at 5 percent level of significance.

Table 1: Variation in Basal area, volume, AG, BG, Total biomass, carbon sequestration inside and outside forest area

	Location	**Basal area (m^2)**	**Volume (kg/m^3/ha)**	**AGB (kg/ha)**	**BGB (kg/ha)**	**Total Biomass (kg/ha)**	**Carbon Sequestration (kg/ha)**
TOTAL	inside	1.3306	241.4042	115874.0392	31285.9905	147160.0298	73580.0149
	road side	0.4529	67.5104	32405.0047	8749.3512	82308.7120	20577.1780

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MEAN	inside	0.0154	2.8070	1347.3725	363.7905	1711.1631	855.5815
	road side	0.0053	0.7942	381.2353	102.9335	484.1688	242.0844
SD	inside	0.0078	1.4367	689.6277	186.1994	875.8272	437.9136
	road side	0.0012	0.1992	95.6616	25.8286	121.4902	60.7451
SE(m)	inside	0.0008	0.1549	74.3644	20.0784	94.4428	47.2214
	road side	0.0001	0.0216	10.3759	2.8015	13.1774	6.5887
CV (%)	inside	50.8728	51.1831	51.1831	51.1831	51.1831	51.1831
	road side	24.1904	25.09254061	25.0925	25.0925	25.0925	25.0925
t-value		11.7269					12.7946
p-value		0^{**}					0^{**}

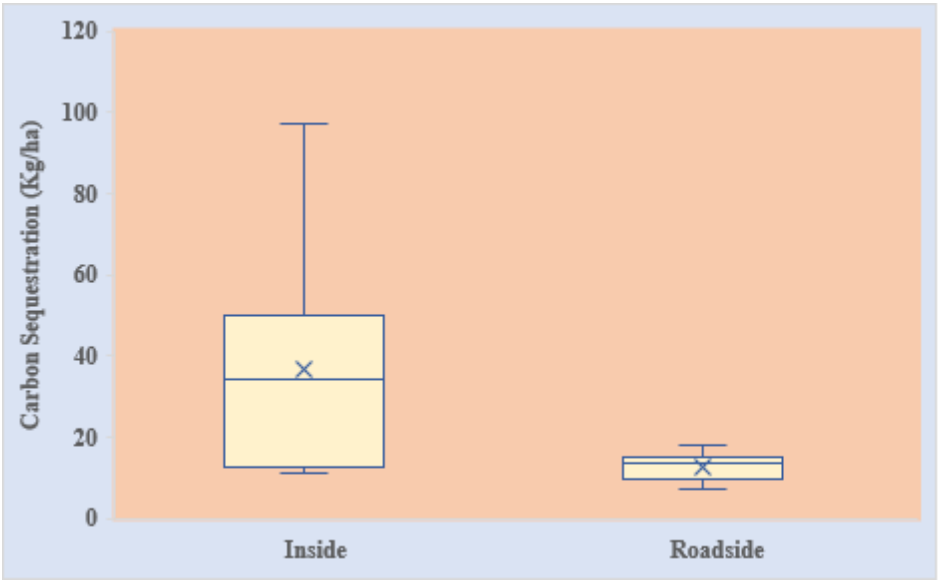

Fig. 1: Box-plot representing the amount of Carbon sequestration (in Kg/ha) inside and roadside of Thithimathi forest area

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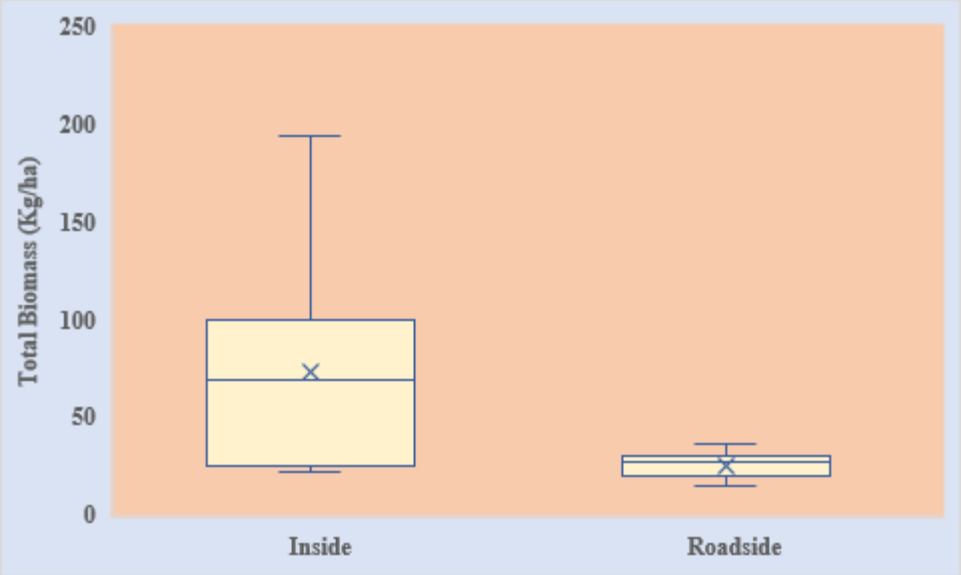

Fig. 2: Box-plot representing the amount of Total Biomass (in Kg/ha) inside and roadside of Thithimathi forest area

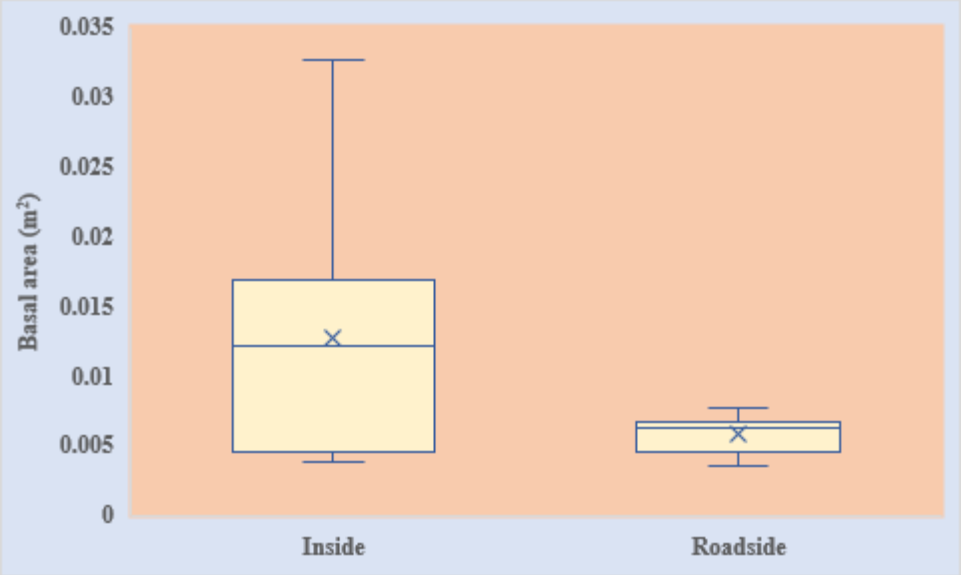

Fig. 3: Box-plot representing the amount of Basal area (m^2) inside and roadside of Thithimathi forest area

Conclusion

This study highlights the significant variation in biomass and carbon sequestration between interior and roadside teak (*Tectona grandis*) plantations in the Thithimati forest. The results clearly demonstrate that interior plantations outperform roadside plantations in terms of basal area, standing volume, total biomass, and carbon storage. Specifically, interior plots sequestered nearly 3.5 times more carbon than roadside plots, underscoring the importance of site conditions in determining the ecological performance of teak plantations.

The findings emphasize that teak plantations, when managed under favourable ecological settings, can serve as effective carbon sinks and contribute meaningfully to climate change mitigation. Moreover, the statistically significant differences observed between the two plantation types suggest that management strategies should prioritize interior forest sites or adopt practices that enhance growth conditions in roadside plantations.

Overall, this research provides quantitative evidence of teak's potential in carbon cycling and reinforces its role in sustainable forestry. By integrating carbon sequestration objectives into plantation management, teak cultivation can simultaneously deliver economic returns and ecological benefits, making it a valuable component of future climate-resilient land use planning.

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