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Impact of citrus-based agroforestry systems on morphological characteristic of trees and carbon sequestration

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Abstract
Green plants can store carbon, which is an effective approach to lower atmospheric CO_2. Forest tree species such as *Tectona grandis*, *Eucalyptus tereticornis*, and *Ailanthus excels* were assessed under a citrus-based agroforestry system for their above ground and belowground carbon sequestration potentials in the present study. The collar diameter (cm) and height (m) of mandarin under different citrus-based agroforestry systems were 3.00, 5.92, 4.72, and 4.70 and 1.47. 2.79, 2.23, and 2.55, respectively. The total standing below-and above-ground biomass of Tectona grandis was 10,63 and 2.76 t ha^{-1},of *Eucalyptus teritocornis* was 49.99 and 12.99 t ha^{-1} and of *Ailanthus excelsa* was 20.34 and 5.28 t ha^{-1}, respectively. In contrast, the total standing biomass in the mentioned species of forest is 1339, 62.98, and 25.62 t ha^{-1}. The standing biomass and AGB and BGB sequestered carbon stocks in *Tectona grandis* were 5.31 and 138 (ha),for *Eucalyptus tereticornis* 24.99 and 6.49 t ha^{-1} and for *Ailanthus excelsa*10.17 and 2.64 t ha^{-1}, correspondingly, 6.69, 31.49, and 12.81 t C ha^{-1} carbon were sequestered in the above forest species.

Keywords: Agroforestry system, Above ground biomass, belowground biomass, Carbon stock, Carbon sequestration

1. Introduction
Greening India is one of the scientific programs, which is targeting to attain 33 percent tree cover of the entire geographical area via agroforestry & social forestry system. Trees are regarded as a terrestrial sink of carbon. Thus, theoretically maintained forests may store carbon both in ex-situ (Products) and situ (biomass & soil). The FAO estimates that the forest plantation globally comprises 187 million hectares, a substantial rise from 1995, the estimate of 124 million hectares. The most quickly growing, short-rotation species, such as Eucalyptus and Acacia, are found in South America and Asia, where there is a record-high annual planting rate of 4.5 million hectares. The carbon sequestration capacity among species of plants, locations, and management varies considerably (Koshta and Upadhya. 2014) [10].

An effective system of agroforestry not only optimizes its benefits but also guaranty its connection to the climate change mitigation. Carbon's huge amounts are filtered from the atmosphere by trees, which would then store that carbon in their biomass. About 23 kg of carbon dioxide may be removed yearly from the atmosphere by a normal tree. The quantity of carbon sequestration is greatly raised in agroforestry systems. The interaction with the various elements of agroforestry may help absorb carbon and other greenhouse gases from the atmosphere and sequester them. Consequently, the existence of trees in an agroforestry system makes it a possible strategy for reducing climate change.

2. Materials and Methods
Nagpur tract fall in the sub-tropical zone, at a latitude of 21" 14" N and longitude 79° 08′ E at a height of 310m above the average level of sea. The area has 3 distinct seasons viz., summer, rainy season, and winter. Most of the precipitation occurs between June and September, with the normal average annual precipitation being 1064 mm. Rare and unpredictable, winter showers do

occurs. The average monthly temperature ranges from 27.70 to 41.70°C in the warmest month (May), and from 14.50 to 29.50° C in the month of cold (December). Measurement of height: It is not advised to remove certain tree species in order to determine their biomass. By measuring the girth at breast height and the diameter at breast height (DBH), mathematical models can help to calculate the biomass. When considering girth, use DBH (Chavan *et al*., 2010) [2]. AGB of a tree: It includes all live biomass that is found above ground. The biomass's volume and density of wood were multiplied to get the aboveground biomass (AGB). The volume has been determined on the basis of height and diameter (Pandya *et al*., 2013) [14]. The estimate of the species wood density were obtained from web (www.worldagroforestry.org)

AGB (g) = volume of biomass (cm3) * wood density (g/cm3)

BGB of a tree: The term "below ground biomass (BGB) refers to any living roots biomass other than those with a diameter of 2 mm (Chavan and Rasal, 2011; 2012) [3, 4]. Tree root biomass estimate formulae are not often found in the literature. By the multiplication of AGB and using 0.26 as a root shoot ratio, the below-ground biomass (RGB) has been determined (Rasal and Chavan, 2011; Hangarge *et al*., 2012) [3, 4, 7].

BGB (g) = 0.26 X AGB (ton)

Total biomass. The sum of the biomass found in AGB and BGB is the TB (Total Biomass)

TB= AGB + BGB

Carbon estimation: According to Pearson *et al*. (2005) [15], any plant species' biomass is often regarded as containing 50% carbon, hence carbon storage is equal to biomass times 50% or biomass /2.

3. Result and Discussion

Effect of tree crops on morphological characters of mandarin under different agroforestry systems

It revealed that all the growth parameters of mandarin showed an increasing trend under different agroforestry systems in comparison to sole mandarin (Table 1). Mandarin's collar diameter (5.92 cm) and height (2.79 m) were at their highest under *Tectona grandis* and their lowest (3.00 cm) and tallest (1.47 m), respectively, in the absence of trees. The outcome demonstrates a considerable variance in the Mandarin development pattern, demonstrating that when the cultivation of crops is done in close proximity to trees, competition exists for nutrients, moisture, and light and that either an interaction negative or positive may arise between them. Additionally, these findings closely align with those of Kumar *et al*. (2013) [11]. Banerjee and Dhura (2011) [1] have found similar traits in the development of diverse trees under various agroforestry systems.

Table 1: Effect of tree crops on morphological characters of Mandarin under different agroforestry systems.

Treatments	Collar Diameter of Mandarin (cm)	Height of Mandarin (m)
Sole Mandarin	3.00	1.47
Mandarin +*Tectona grandis*	5.92	2.79
Mandarin + *Eucalyptus tereticornis*	4.72	2.23
Mandarin +*Ailanthus excelsa*	4.70	2.55

Effect of tree crops on morphological characteristics of forest trees under different agroforestry systems:

It showed that the *Tectona grandis*, *Eucalyptus teretocornis*, and *Ailanthus excelsa* recorded the highest tree GBH (64.00 cm) and tree collar diameter (82.75 cm) (Table 2). While *Eucalyptus tereticornis* (11.64 m) was the tallest tree measured, it was followed in height by *Tectona grandis* and *Ailanthus excelsa*. Maximum tree crown width (7.50 m) and tree crown length (7.39 m) was recorded in *Ailanthus excelsa* agroforestry systems. In contrast to only having trees and fruit trees (no crop in the spaces between the trees and fruit trees), Dhara (2016) [5] found that all the growth-attributing characteristics of silvi species and yield of fruits have been on the greater side where the crops growth seen in the interspaces of fruit-based agroforestry systems, demonstrating a favorable impact of intercropping on the silvi growth and fruit trees.

Table 2: Effect of tree crops on morphological characteristics of trees under different agroforestry systems.

Treatments	Tree GBH (cm)	Tree collar diameter (cm)	Tree height (m)	Tree crown width (m)	Tree crown length(m)
Mandarin + *Tectonagrandis*	36.75	57.50	5.70	3.86	3.03
Mandarin + Eucalyptus tereticornis	62.25	75.25	11.64	4.89	3.68
Mandarin +Ailanthus excelsa	64.00	82.75	5.98	7.50	7.39

Effect of tree crops on tree volume ha', AGB, BGB, and TB (t ha¹) of various forest species under different agroforestry systems

Table 3. revealed that the *Eucalyptus tereticornis* recorded maximum tree volume (0.282m tree) and tree volume per hectare (78.11 m ha^{-1}) followed by *Tectona grandis* as well as *Ailanthus excelsa*. The standing biomass in *Eucalyptus tereticornis* showed the highest aboveground, belowground, and total standing biomass (49.99, 12.99, and 62.98 t ha' each) followed by *Ailanthus excelsa* (20.34,5.28, and 25.62 t ha^{-1} each) and *Tectona grandis* (10.63.2.76 and 13.39 t ha^{-1} each). In comparison to *Tectona grandis* and *Ailanthus excelsa*, the total standing biomass of *Eucalyptus tereticornis* was 75.94 and 48.10 percent greater, respectively. In the experimental agroforestry system, the total above-ground, below-ground, and standing biomass were 80.96, 21.03, and 101.99 t ha', respectively. Rai *et al*. (2009 have reported carbon storage capacity varying from 1.89 to 3.45 t C ha^{-1}, and the biomass accumulation 8.6,6.92,652, 6.25, and 6.41 t ha^{-1} for *Albizia procera*, *Eucalyptus tereticornis*, *Albiziala back*, and *Emblica officinalis.*

Table 3: Effect of tree crops on tree volume ha, AGB, BGB, and TB (t ha) of various forest species under different agroforestry systems.

Treatments	Tree volume ($m^3 tree^1$)	Tree volume ($m^3 tree^1$)	AGB (t ha^{-1})	BGB (t ha^{-1})	Total standing biomass (t ha^{-1})
Mandarin + *Tectonagrandis*	0.048	13.29	10.63	2.76	13.39
Mandarin + Eucalyptus tereticornis	0.282	78.11	49.99	12.99	62.98
Mandarin +Ailanthus excelsa	0.153	42.38	20.34	5.28	25.62
Total		133.78	80.96	21.03	101.99

Effect of tree crop on aboveground, belowground, and total carbon sequestrated (t ha^{-1}) in different forest species

The concentrated carbon of various tree components has been seldom examined directly but was instead expected to be 50% of the dry weight based on literature since the carbon content of woody biomass in any constituent of a forest is often around 50% of dry matter (Losi *et al*., 2003; Jana *et al*., 2009) [12, 9]. By adding the below - and above-ground carbon stalks of a few different forest species, the total carbon stock of a tree was calculated (t ha^{-1}). Result revealed that *Eucalyptus tereticornis* tree containing the highest aboveground, belowground and total carbon sequestrated 24.99, 6.49 and 31.491 t $ha^{-1,}$ respectively followed by *Ailanthus excelsa* 10.17, 2.64 and 12.81 t $ha^{-1,}$ respectively and *Tectona grandis* (5.31. 138 and 669 t $ha^{-1,}$ respectively (Table 4). Comparing the amount of carbon sequestered by *Eucalyptus tereticornis* with that of *Ailanthus excelsa* and *Tectons grandis*, the difference was 48.18 and 7934 percent. In semiarid, humid, temperate, and sub-humid environments, the total storage of carbon by agroforestry was 9,21,50, and 63 Mg Cha. According to Dhyani *et al*. (2009) [6], cultivations of food crops, as well as trees, capture 40 percent and 84 percent less carbon than agrisilviculture, respectively, showing that systems of the agroforestry have a greater capacity to do so. Ilorkar (2014) also reported the total above-ground carbon storage which varied from 1.819 th to 6,568 tha".

They also recorded the highest carbon sequestration (6.568tha) for *Dalbergia sisoo*, followed by *Eucalyptus tereticornis* and *Tectonagrandis*. The lowest carbon sequestration was observed under *Tectonagrandis* (1815tha') due to low tree density and lower age of the system.

Table 4: Effect of a tree crop on aboveground, belowground, and total carbon sequestrated (the) in different forest species.

Treatments	Above Ground Carbon (t ha^{-1})	Below Ground Carbon (t ha^{-1})	Total Carbon Sequestrated (t ha^{-1})
Mandarin + *Tectonagrandis*	5.31	1.38	6.69
Mandarin + Eucalyptus tereticornis	24.99	6.49	31.49
Mandarin +Ailanthus excelsa	10.17	2.64	12.81
Total	40.47	19.55	101.99

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