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Carbon sequestration potential of silvicultural and horticultural tree species under different multitier cropping systems

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ABSTRACT

Agroforestry plays a better role in increasing agricultural productivity by nutrient recycling, reducing soil erosion, and improving soil fertility and enhancing farm income compared with conventional crop production. Furthermore, it has promising potentials for reducing deforestation while increasing food, fodder, and fuelwood production. Agroforestry practices can reduce the atmospheric concentration of CO_2 by increasing carbon storage in biomass, decreasing emission at source and modifying agricultural practices to increase the quantity of carbon stored in soil organic matter. The natural cycling of the carbon is maintained and controlled by a dynamic balance between biological and inorganic processes since the geological history of the earth. In the terrestrial ecosystem, carbon is sequestered in rocks and sediments, wetlands and forests, and in the soils of forestland, grasslands and agricultural land. In this paper, the estimation of the biomass and carbon sequestration rates of silvicultural and horticultural tree species under Horti-silviculture and Agri-Horti-Silviculture agroforestry system has been done. This investigation is proof to substantiate the fact that adoption of agroforestry techniques/systems is not only beneficial to farmers from their economic perspective but at the same time agroforestry systems helps to reduce global warming and rejuvenate the earth's atmosphere. In four years of study carbon sequestered in the following manner: Grevillea robusta > Dalbergia sissoo > Syzygium cumini> Mangifera indica> Anacardium occidentale > Eucalyptus globules. When compared according to silvicultural and horticultural categories it Syzygium cumini was found most efficient among horticultural tree species while Grevillea robusta was most efficient among selected tree species.

Keywords: *Carbon Sequestration, Agroforestry, Horticultural and Silvicultural Tree.*

1. INTRODUCTION

Carbon exists in the earth's atmosphere primarily as the gas-carbon dioxide. It constitutes a very small percentage of the atmosphere about 0.04% approximately. However, it plays an important role in supporting life on earth, as plants make themselves from it. During photosynthesis, plants take up carbon dioxide from the atmosphere, converting it into carbohydrate and releasing oxygen into the atmosphere. When these plants or trees die or are burnt, the carbon stored in them are released back into the atmosphere. This natural cycling of the carbon is maintained and controlled by a dynamic balance between biological and inorganic processes since the geological history of earth[1]. In the terrestrial ecosystem, carbon is sequestered in rocks and sediments, wetlands and forests, and in the soils of forestland, grasslands and agricultural land.

Carbon sequestration is the process of removing C from the atmosphere and depositing it in a reservoir. It entails the transfer of atmospheric C, especially CO2, and its secure storage in long-lived pools [2]. The long-term global C cycle that describes the biogeochemical cycling of C among surface systems consisting of oceans, the atmosphere, biosphere, and soil controls the atmospheric CO2 concentration over geological time scales of more than 100,000 years[3]. The short-term C cycle over decades and centuries is of greater importance than the long-term cycle in forest, AFS, and agricultural ecosystems. The important processes of this cycle are the fixation of atmospheric CO2 in plants through photosynthesis and return of part of that C to the atmosphere through plant, animal, and microbial respiration as CO2 under aerobic and CH4 under anaerobic conditions.

Vegetation fires, and burning and land clearing for cultivation for agricultural and forestry purposes, can also release significant quantities of CO_2 (and CH_4) to the atmosphere; but much of this C is recaptured in subsequent regrowth of vegetation [4,5]. Carbon pools in such terrestrial systems include the aboveground plant biomass, durable products derived from biomass such as timber, and belowground biomass such as roots, soil microorganisms, and the relatively stable forms of organic and inorganic C in soils and deeper subsurface environments. Thus, from the agroforestry[19] point of view, Carbon Sequestration involves primarily the uptake of atmospheric CO2 during photosynthesis and transfer of fixed C into vegetation, detritus, and soil pools for ''secure'' storage.

The Soil Science Society of America (SSSA) recognizes that C is sequestered in soils in two ways: direct and indirect [6]. Direct soil Carbon Sequestration occurs by inorganic chemical reactions that convert CO2 into soil inorganic C compounds such as calcium and magnesium carbonates. Indirect plant Carbon Sequestration Au5 occurs as plants photosynthesize atmospheric CO2 into plant biomass. Some of this plant biomass is then sequestered as soil organic carbon (SOC) during decomposition processes. The amount of soil C sequestered at a site reflects the long-term balance between C uptake and release mechanisms. Because those flux rates are large, changes such as shifts in land cover and/or land-use practices that affect pools and fluxes of SOC have large implications for the C cycle and the earth's climate system.

It is clear from the above that Carbon Sequestration occurs in two major segments of the agroforestry ecosystem: aboveground and belowground. Each can be partitioned into sub segments: the former into specific plant parts (stem, leaves, etc. of trees and herbaceous components), and the latter into living biomass such as roots and other belowground plant parts, soil organisms and C stored in various soil horizons. The total amount sequestered in each part differs greatly depending on a number of factors, including the region, the type of system (and the nature of components and age of perennials such as trees), site quality, and previous land-use. On average, the soil and aboveground parts are estimated to hold major portions, roughly 60% and 30%, respectively, of the total C stored in tree-based land-use systems [7,8]. Based on the notion that tree incorporation in croplands and pastures would result in greater net C storage above- and belowground [9, 10] AFSs are believed to have a higher potential to sequester C than pastures or field [11]

In this paper, the estimation of the biomass and carbon sequestration rates of silvicultural and horticultural tree species under Horti-silviculture and Agri-horti-silviculture agroforestry system has been done. This investigation is a proof to substantiate the fact that adaption of agroforestry techniques / system is not only beneficial to farmers for their economic perspective but at the same time agroforestry systems helps to reduce global warming and rejuvenate the earth's atmosphere.

2. MATERIAL AND METHODS

2.1. Study location

The present study was carried out in capital of Jharkhand state , Ranchi. The district lies in south chotanagpur administrative division located at 23.35°N latitude, 85.33°E longitude near to the Tropic of Cancer and altitude varies from 500 to 700 m above mean sea level (MSL). Ranchi has a relatively moderate climate compared to rest of state of India with hilly topography. For investigation total 2 plots were selected under different agroforestry systems in Research Extension Cum demonstration centre Garhkhantanga, Ranchi, Jharkhand (Under Administrative control of Plantation Research and Evaluation circle of Ministry of Forest Environment and Climate Change, Government of Jharkhand).

Plot 1: Agri-Horti-Silviculture: Plot consists of mixed plantation of multi-storey trees such as *Darbergia sisoo* (Sisum), *Grevillea robusta* (silver oak) which were forest tree species ; fruit trees consists of: *Magnifera indica* (Mango), *Anacardium occidentale* (Kaju) and s Syzygium cumini (Jamun)

Plot 2: Horti-Silviculture: This plot consists of *Eucalyptus globules* Eucalyptus trees as plantation.
The study area of two agroforestry systems was divided equally into three replications of 10x10 m and in each replication all trees were selected and enumerated. In all three study sites a total of 200 trees were selected. 100 trees of Eucalyptus globules in Hortisilviculture system, 100 trees of *Darbergia sisoo* (Sisum), *Grevillea robusta* (silver oak) *Magnifera indica* (Mango), *Anacardium occidentale (*Kaju), and *Syzygium cumini*(Jamun) each 20 in number in agri-horti-silviculture system. The selected trees were 10-12 years old. During four years of study following parameters were measured for estimating the carbon sequestration potential of each species.

2.2. Measurement of Height

To estimate biomass from selective tree species, it is not advisable to cut them. The biomass can be measured by mathematical models by measuring diameter at breast height (DBH) directly and the girth at DBH. Girth considered is the DBH [12]

2.3. Above Ground Biomass of Tree

AGB include all living biomass above the soil. The aboveground biomass (AGB) has been calculated by multiplying volume of biomass and wood density the volume was calculated based on diameter and height [16] . The wood density value for the species obtained from web (www.worldagroforestry.org). Species wise wood density is mentioned in table 1

$$\text{AGB (g)} = \text{volume of biomass (cm}^3\text{)} \times \text{wood density (g/ cm}^3\text{)}$$

Table 1 : Represents the standard wood densities of selected tree species

	Scientific Name	Vernacular Name	Wood density (g/cm^3)
1.	*Dalbergia sisoo*	Sisum	0.6934
2.	*Grevillea robusta*	Robusta	0.5360
3.	*Mangifera indica L*	Mango	0.5977
4.	*Anacardium occidentale*	Kaju	0.4541

5.	*Syzygium cumini*	Jamun	0.7011
6.	*Eucalyptus globules*	Eucalyptus	0.7093

2.4. Below Ground Biomass of Tree

The below ground biomass (BGB) include all biomass of live roots excluding find roots having,<2 mm diameter [13,14]. Biomass estimation equations for tree roots are relatively uncommon in the literature. The belowground biomass (BGB) has been calculated by multiplying above ground biomass taking 0.26 as the root shoot ratio[13, 15]

BGB (g) = 0.26 X above ground biomass (ton)

Total Biomass Total biomass is the sum of the above and below ground biomass[17].

Total Biomass (TB) = Above Ground Biomass + Below Ground Biomass

2.5. Carbon Estimation

Generally, for any plant species 50% of its biomass is considered as carbon [18]
i.e., Carbon Storage = Biomass x 50% or Biomass/2

3. RESULT AND DISCUSSION

Field data of trees from study area were tabulated and it reveals that there are six species (three silvicultural species and three horticultural species) which are investigated to know carbon sequestration potential of each species. It also indicates the average DBH in cm and average tree heights in meters. The mean above ground biomass (AGB) per tree (Kg/tree); mean of below ground biomass (BGB) per tree (Kg/tree); the total tree biomass (TTB) of each species in Kg and the carbon sequestrated by each species in span of four years have been summarized. The organic carbon sequestrated in per species is shown for comparison purpose also. It is found most efficient tree species for carbon sequestration is *Grevillea robusta* among other species followed by *Dalbergia sisoo.* Total Carbon sequestered by a tree per years by these species are 26.19 ton/treeand 22.83 ton/tree respectively. Least carbon sequestrating tree species among selected tree species are *Eucalyptus globules* followed by *Anacardium occidentale* and *Mangifera indica.* Results were found caparable to the studies carried on by Suryawanshi *et.al.*, (2014) [20], Bohre *et a*l., (2012) [21]

In four years of study carbon sequestered in following manner: *Grevillea robusta (*107.41 ton/tree)> *Dalbergia sisoo (*91.31 ton/tree*)*> *Syzygium cumini (*85.62 ton/tree*)*> *Mangifera indica (*43.19 ton/tree*)*> *Anacardium occidentale (*37.31 ton/tree*)*> *Eucalyptus globules (*35.15 ton/tree*).* When compared according to silvicultural and horticultural categories it *Syzygium cumini* was found most efficient among horticultural tree species while *Grevillea robusta* was most efficient among selected tree species.

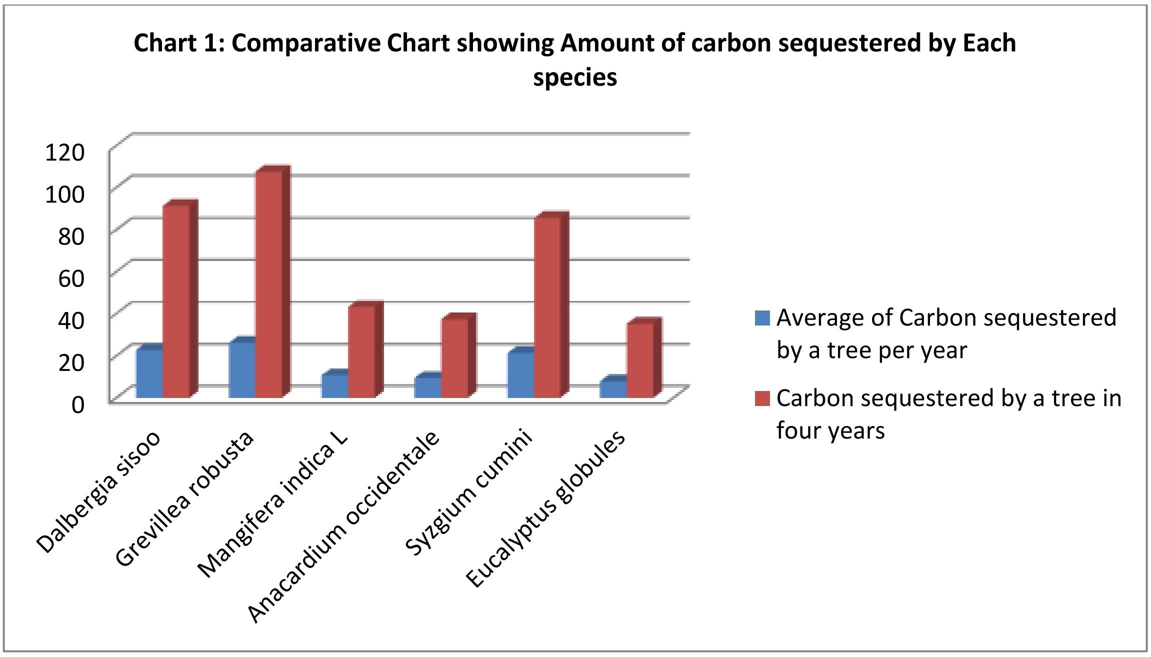

Table 2: Field data of selected tree species to show the total tree biomass and carbon sequestration

	Year	Height (m)	DBH (Cm)	Above ground biomass (kg /tree)	Below Ground Biomass (kg /tree)	Total Tree Biomass (kg /tree)	Carbon sequestration (ton/tree)
	Horti-Silviculture Agroforestry system						
E.globulus	**2017**	11.72	28.74	5414.59	1407.79	6822.39	3.76
	2018	14.35	34.78	9692.44	2520.03	12212.48	6.73
	2019	17.57	35.42	12247.65	3184.39	15432.04	8.51

	2020	19.53	40.14	17489.86	4547.36	22037.22	12.15
	Grand mean	**15.79**	**34.77**	**11211.14**	**2914.90**	**14126.03**	**7.79**
	Total Carbon sequestered by a tree in four years = 35.15 ton/tree						
	Agri-Horti-Silviculture Agroforestry system						
M.indica	**2017**	4.97	23.85	1370.12	356.23	1726.35	7.77
	2018	5.39	24.85	1610.15	418.64	2028.79	9.13
	2019	5.81	25.85	1871.44	486.57	2358.01	10.61
	2020	6.93	28.85	2764.76	718.84	3483.60	15.68
	Grand mean	**5.78**	**25.85**	**1904.12**	**495.07**	**2399.19**	**10.80**
	Total Carbon sequestered by a tree in four years = 43.19 ton/tree						
D.sisoo	2017	8.19	26.10	3118.14	810.72	3928.85	17.68
	2018	8.73	26.85	3527.38	917.12	4444.49	20.00
	2019	9.03	28.10	3970.45	1032.32	5002.76	22.51
	2020	10.28	31.10	5488.60	1427.04	6915.64	31.12
	Grand mean	**9.06**	**28.04**	**4026.14**	**1046.80**	**5072.94**	**22.83**
	Total Carbon sequestered by a tree in four years =91.31 ton/tree						
G.robusta	2017	10.22	29.05	3701.67	962.44	4664.11	20.99
	2018	10.70	30.45	4271.73	1110.65	5382.38	24.22
	2019	10.76	31.05	4434.51	1152.97	5587.48	25.14
	2020	12.24	34.05	6066.27	1577.23	7643.50	34.40
	Grand mean	**10.98**	**31.15**	**4618.55**	**1200.82**	**5819.37**	**26.19**
	Total Carbon sequestered by a tree in four years =107.41 ton/tree						
S.cumini	**2017**	7.74	25.90	2892.26	751.99	3644.25	16.40
	2018	8.16	26.90	3286.76	854.56	4141.32	18.64
	2019	8.59	27.90	3715.15	965.94	4681.09	21.06
	2020	9.84	30.90	5206.94	1353.81	6560.75	29.52
	Grand mean	**8.58**	**27.90**	**3775.28**	**981.57**	**4756.85**	**21.41**
	Total Carbon sequestered by a tree in four years =85.62 ton/tree						
A.occidental	**2017**	10.22	23.10	2022.23	525.78	2548.01	11.47
	2018	4.51	24.05	965.21	250.96	1216.17	5.47
	2019	5.05	26.55	1400.11	364.03	1764.14	7.94
	2020	6.93	29.00	2262.79	588.33	2851.11	12.83
	Grand mean	**6.68**	**25.68**	**1662.59**	**432.27**	**2094.86**	**9.43**
	Total Carbon sequestered by a tree in four years =37.31 ton/tree						

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