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Assessment of Carbon Sequestration Potential of Standing Tree Borne Oilseed Species (TBOs) in UAS, GKVK Campus, Bengaluru, India

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Abstract

In order to fight the ever-increasing pressure on forest and to reduce the CO_2 levels in atmosphere, cultivating trees on arable lands has become necessary. In this context, a field experiment was carried out in UAS, GKVK, Bengaluru to study the growth performance and amount of carbon sequestered by tree borne oilseed species. The experiment was laid out in Randomised Complete Block Design with seven treatments *i.e*., tree species (*Simarouba glauca, Melia dubia, Azadirachta indica, Melia azedarach, Pongamia pinnata, Madhuca latifolia* and *Calophyllum inophyllum*) and replicated three times. Biomass was calculated using Non-destructive allometric models. Based on the performance of growth and yield trait analysis, *Melia dubia* recorded significantly higher tree height (12.72 m), DBH (38.61 cm), wood volume (0.848 m^3) and canopy spread (14.78 m in N-S and 11.91 m in S-W direction) as against other tree species. *Melia dubia* was able to sequester 268.4 tonnes of CO_2 followed by *Simarouba glauca* which sequestered 162.5 tonnes of CO_2 and *Pongamia pinnata* which captured 150.5 tonnes of CO_2. This indicated that, *Melia dubia, Simarouba glauca* and *Pongamia pinnata* were highly promising tree species for carbon sequestration over other tree species.

Keywords: Carbon Sequestration, Tree Borne Oilseed species, Non-destructive allometric models

NEVER before in the history of human civilization has environmental issues attained so much global prominence as it does today. Hardly a day passes without some aspect of it hitting the headlines. The award of the Nobel Peace Prize 2007 to Al Gore and the Intergovernmental Panel on Climate Change (IPCC) of the United Nations (UN) for raising global awareness about the severity of human-induced climate change was a defining moment in history. According to the World Wide Fund for Nature, we are losing 130,000 square km of forest cover every day. This rapid loss of natural forest across the world is increasingly concerning. Forest goods and services, once thought to be abundant, are now a scarce resource. In order to fight the ever-increasing pressure on forest and to utilize the natural resources in a sustainable way for production of goods and services, cultivating trees on arable lands has become necessary. Seeds rich in non-edible oils produced by perennial species are known as tree borne oilseeds species (TBOS) and they yield tree borne oilseeds (TBOs). In India, many of the TBOs were being traditionally utilized for fuel purpose in countryside and now are being cultivated in different agro-climatic conditions in addition to wasteland, deserts and hilly areas. The promising tree borne oilseed species not demanding the crops can be grown on marginal or degraded land without competing for more fertile lands required by food crops (Sims *et al.,* 2008). India is the first country to frame the National Agroforestry Policy which was adopted in the year 2014. National Agroforestry Policy (NAP) elaborates that agroforestry is a dynamic, ecologically based, natural resource management system that integrates woody perennials on farms and in agricultural landscapes that diversifies and sustains production and builds social institutions. One of the major goals of this policy is conserving the natural resources and forests, protecting the environment and increasing the forest/ tree cover. (MoA, 2014).

Trees are potential to check the climate change effects through microclimate moderation and conservation of natural resources in the short run and through storage of carbon in the long run, which is far greater than the crop and grass systems. Currently, global warming is more certain and alarming than ever. Due to steady increase of CO_2 in the atmosphere, *i.e.* from 280 ppm in 1850 up to 407 ppm in 2018, the global average temperature is soaring drastically (NOAA, 2018). Thus increasing CO_2 emission is one of the major environmental concerns and it has been well addressed in Kyoto Protocol. Under current situation, one of the effective ways to cope up with increasing CO_2 levels in the atmosphere is by binding the atmospheric CO_2 in long-lived carbon pools of plant biomass and in soils through a process known as carbon sequestration.

As more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering it in plant tissue above and below ground (IPCC, 2003) resulting in growth of different parts (Chavan and Rasal, 2010). Forests occupy more than one third of the world's terrestrial region and constitute the major terrestrial carbon pool (Roberntz and Sune, 1999). Forest ecosystem act as a reservoir of carbon by holding enormous quantities of carbon and plays substantial role in the global carbon cycle by accumulating ample amount of CO_2 from the atmosphere (Vashum and Jay Kumar, 2012).

In the present scenario of rising atmospheric carbon dioxide levels coupled with increase in temperature, it is crucial to have accurate information about the spatial distribution of carbon both in soil and vegetation in the ecosystem for understanding the biogeochemical processes and formulation of policies and actions in mitigating global warming and climate change.

Considering the above facts, present investigation was undertaken with the following objectives:

1. To evaluate the growth performance of tree borne oilseed species and
2. To assess the extent of carbon sequestration by tree borne oilseed species.

Methodology

The experiment was conducted at University of Agricultural Sciences, GKVK, Bengaluru situated in the Eastern Dry Zone (Zone - 5) of Karnataka. The experimental site is located between 12º 51' N Latitude and 77º 35' E Longitude at an altitude of 930 m above mean sea level (MSL). The experiment was laid out in Randomized Complete Block Design (RCBD) with seven treatments replicated thrice. Seven tree borne oilseed species were selected for conducting the experiment. These trees were planted during 2008 at a spacing of 10 m between the row and 5 m between the plants within the row comprising of nine trees in each plot. Trees include the following

1. *Simarouba glauca*
2. *Melia dubia*
3. *Azadirachta indica*
4. *Melia azedarach*
5. *Pongamia pinnata*
6. *Madhuca latifolia*
7. *Calophyllum inophyllum*

Observations on various morphological parameters like tree height, DBH, total tree volume and canopy spread to assess the growth of TBOs were recorded from five randomly selected trees from each plot. The initial growth parameters of tree borne oilseed species like tree height, DBH, canopy spread, total wood volume and total tree biomass which were recorded in 2012 is presented in Table 1.

Quantifying the Amount of Carbon Sequestration

To estimate the biomass of the tree, it is not advisable to cut them. Hence, the total biomass of the tree was determined by non-destructive method using mathematical models by measuring DBH and height (Chavan *et al*., 2010). The aboveground biomass (AGB) of tree was calculated by multiplying volume of biomass of each tree species with its respective wood density and the volume was calculated based on diameter and height (Pandya *et al*., 2013). It was expressed in tonnes per hectare. Wood density is used from Global wood density database (Zanne *et al*., 2009) is considered since the wood density of Indian tree species is similar to that of Global wood density.

TABLE 1
Morphological parameters of the tree species during 2012

Tree species	Tree height (m)	DBH (cm)	Canopy spread (m)		Total tree volume (m^3)	Tree biomass (t/ha)
			N - S	E - W		
Simarouba glauca	7.26	14.00	3.36	3.80	0.023	12.94
Melia dubia	9.02	23.00	7.91	7.55	0.103	39.95
Azadirachta indica	5.14	11.00	3.16	3.13	0.017	7.73
Melia azedarach	8.09	14.00	4.43	4.38	0.034	11.81
Pongamia pinnata	3.46	8.00	3.10	3.11	0.006	3.30
Madhuca latifolia	3.41	7.00	1.61	1.54	0.002	2.34
C. inophyllum	2.75	-	1.65	1.70	0.002	2.27
S.Em±	0.55	0.52	0.44	0.44	0.02	2.21
CD at 5 %	1.20	1.60	0.97	0.97	0.03	4.82

TABLE 2
Chemical properties of soil in the experimental site at agroforestry unit, UAS, ZARS, GKVK, Bengaluru in the year 2012

Particulars	Values	Status	Method followed
pH	6.20	neutral	Potentiometric method Jackson (1973)
EC (dS m^{-1})	0.52	low	Conductometric method Jackson (1973)
Organic carbon (%)	0.49	medium	Wet oxidation method Walkley and Black (1934)
Available nitrogen (kg ha^{-1})	248.33	low	Alkaline potassium permanganate method Subbaiah and Asija (1956)
Available phosphorus (kg ha^{-1})	19.61	medium	Brays extract Jackson (1973)
Available potassium (kg ha^{-1})	223.61	medium	Flame photometry Jackson (1973)

Above ground biomass (t ha^{-1}) = volume of biomass (m^3 ha^{-1}) × wood density (g cm^{-3})

The below ground biomass (BGB) was calculated by multiplying above ground biomass taking 0.26 as the root: shoot ratio (Chavan and Rasal, 2011; Hangarge *et al.,* 2012) and was expressed in tonnes per hectare.

Below ground biomass (t ha^{-1}) = Above ground biomass (t ha^{-1}) × 0.26

Total biomass of tree is the sum of the above and below ground biomass (Sheikh *et al*., 2011) and was expressed in tonnes per hectare.

The amount of carbon sequestered by the tree was estimated by reducing the total biomass of the tree to 50 percent (Pearson *et al*., 2005) or by multiplying the total biomass of tree with 0.5 (Mac Dicken, 1997) and was expressed in tonnes per hectare.

Tree carbon sequestration (t ha^{-1}) = Total biomass ÷ 2

The amount of soil organic carbon sequestered in soil was calculated by using the following equation (Broos and Baldock, 2008) and was expressed in tonnes per hectare.

Soil organic carbon (t ha^{-1}) = Depth (cm) x Bulk Density (g cm^{-3}) x Organic Carbon (%)

TABLE 3

Meteorological data indicating actual for the year 2018 and normal 1976 to 2017 at UAS, GKVK, Bengaluru

Month	Rainfall (mm)		Rainy days		Temperature °C				S.H (hrs.)		W.S. (km/hr.)		R.H (%)			
	N	A	N	A	N		A		N	A	N	A	N		A	
					Max	Min	Max	Min					Max	Min	Max	Min
January	1.5	4.8	0	0	27.4	14.0	27.4	14.1	8.9	8.7	6.8	5.4	86	44	87	52
February	8.8	3.0	0	0	30	15.4	29.4	15.3	9.6	9.5	6.8	7.5	81	38	86	48
March	16.7	62.2	1	3	32.7	17.9	32	17.7	9.3	8.6	6.9	6.9	76	33	78	35
April	47.1	37.0	3	1	33.7	20.5	33.2	20.8	8.8	8.5	6.5	5.5	79	35	83	39
May	101.0	229.4	6	12	33	20.5	31.7	20.1	8.3	7.4	8.0	5.1	82	40	86	43
June	80.7	29.6	6	2	29.5	19.5	28.6	19.7	5.9	5.2	12.2	9.2	86	52	90	54
July	104.9	62.6	8	4	28.2	19.1	27.7	19.5	4.4	4.0	11.9	9.9	88	56	92	57
August	128.2	97.8	10	7	27.7	18.9	27.0	18.8	4.7	3.5	10.1	9.0	90	58	94	60
September	194.2	153.6	9	11	28.1	18.9	29.2	19.2	5.7	6.5	7.1	5.0	89	57	92	50
October	162.6	29.2	8	6	27.9	18.3	28.9	17.8	6.1	7.5	5.5	5.4	88	57	91	54
November	57.2	20.6	4	4	26.7	16.6	28.4	16.9	6.5	7.2	6.2	7.3	87	56	89	54
December	13.1	2.8	1	1	26.3	14.6	27.8	16.3	7.3	6.3	6.8	6.1	87	51	89	54
Total	915.8	732.6	56	51	_	_	_	_	_	_	_	_	_	_	_	_

RESULTS AND DISCUSSION

Tree Growth Parameters

The tree growth is first and foremost a species dependent factor that is influenced by predominant agro-ecological conditions. The tree productivity *i.e.,* the amount of biomass that a tree can grow over a period of time is a function of net rate of photosynthesis. Accordingly, the growth parameters of tree such as tree height (m), Diameter at Breast Height (DBH), canopy spread towards East-West and North-South direction and total tree volume (m^3) differed significantly among different tree species and results are presented in Table 4.

The tallest tree among the seven tree species was *Melia dubia* which recorded an average height of 12.72 m. This was followed by *Melia azedarach* (10.89 m), *Simarouba glauca* (9.33 m) and *Azadirachta indica* (9.36 m). The DBH was significantly higher in *Melia dubia* which recorded 38.61 cm followed by *Simarouba glauca* (23.21 cm), *Pongamia pinnata* (22.64 cm) and *Azadirachta indica* (21.94 cm). Considerably higher canopy spread was witnessed in *Melia dubia* (14.78 m) followed by *Simarouba glauca* (8.81 m) in north-south direction. The canopy spread was considerably higher in *Melia dubia* (11.91 m) followed by *Simarouba glauca* (8.41 m) in east-west direction. The average tree volume was significantly higher in *Melia dubia* which recorded 0.848 m^3. This was followed by *Simarouba glauca* (0.214 m^3), *Azadirachta indica* (0.189 m^3), *Melia azedarach* (0.140 m^3) and *Pongamia pinnata* (0.130 m^3).

Quantifying the Amount of Carbon Sequestration

Trees act as carbon pools and help in mitigating the detrimental effects of climate change. The results have indicated that there is wider scope for atmospheric

TABLE 4
Growth parameters of different tree borne oilseed species established at UAS, GKVK campus, Bengaluru

Tree species	Tree height (m)	DBH (cm)	Canopy spread (m)		Total tree volume (m^3)
			N - S	E - W	
Simarouba glauca	9.33	23.21	8.81	8.41	0.214
Melia dubia	12.72	38.61	14.78	11.91	0.848
Azadirachta indica	9.36	21.94	6.26	5.49	0.189
Melia azedarach	10.89	18.12	6.88	6.19	0.140
Pongamia pinnata	6.20	22.64	7.65	7.40	0.130
Madhuca latifolia	6.03	19.64	3.85	3.91	0.098
Calophyllum inophyllum	4.97	9.64	3.11	2.82	0.017
S.Em±	0.12	0.19	0.05	0.05	0.01
CD at 5%	0.35	0.59	0.15	0.14	0.03

carbon sequestration through agroforestry system. The total biomass of the tree was determined by non-destructive method using mathematical models and the results are presented and discussed below.

Total Biomass of Tree

Melia dubia recorded significantly higher above ground biomass of 67.84 t ha^{-1}. This was followed by *Azadirachta indica* (26.04 t ha^{-1}) and *Simarouba glauca* (24.79 t ha^{-1}) which were on par with each other. Significantly higher below ground biomass was recorded by *Melia dubia* (17.63 t ha^{-1}). Next in the order was *Azadirachta indica* (6.77 t ha^{-1}) and *Simarouba glauca* (6.44 t ha^{-1}). Significantly higher total biomass of tree was recorded by *Melia dubia* (85.47 t ha^{-1}). Next in the order was *Azadirachta indica* (32.81 t ha^{-1}) and *Simarouba glauca* (31.23 t ha^{-1}). The results were in similarity with the findings (Fig. 1). of Roy *et al.* (2006) and Ahmedin *et al.* (2013).

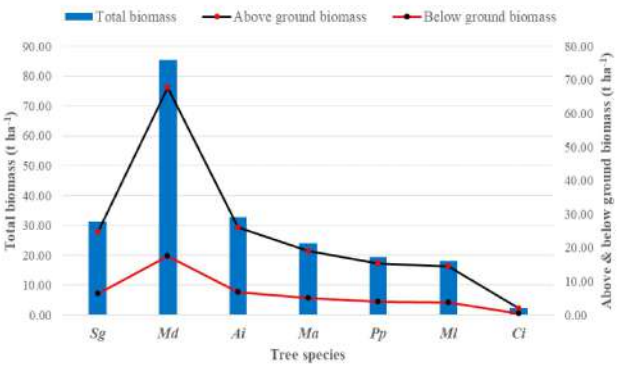

Fig. 1 Above-ground, below-ground and total biomass of different tree borne oilseed species established in GKVK campus, Bengaluru

Tree Carbon Stock

The tree carbon stock of different tree species differed significantly (Table 5). The above ground carbon stock was significantly higher in *Melia dubia* (42.73 t ha^{-1}). This was followed by *Azadirachta indica* (16.40 t

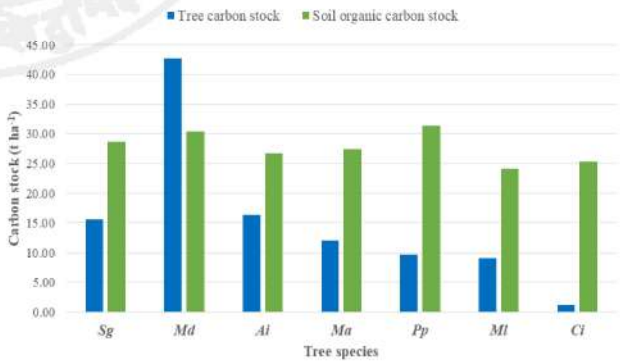

Fig. 2 Tree carbon stock and soil organic carbon stock of different tree borne oilseed species established in GKVK campus, Bengaluru

Note : Sg: Simarouba glauca Md: Melia dubia Ai: Azadirachta indica Ma: Melia azedarach Pp: Pongamia pinnata Ml: Madhuca latifolia Ci: Calophyllum inophyllum

ha^{-1}) and *Simarouba glauca* (15.61 t ha^{-1}). Significantly lower tree C stock was witnessed in *Calophyllum inophyllum* with 1.21 t ha^{-1}. The significant difference witnessed in tree carbon stock of different tree species depended on region, species, age of tree and previous land-use pattern. The results were in similarity with the findings of (Fig. 2.) Ganguly and Mukherjee (2016).

Soil Organic Carbon Stock

A significant difference was noticed in soil organic carbon stock among different tree species (Table 5). *Pongamia pinnata* recorded significantly higher soil organic carbon stock of 31.35 t ha^{-1} followed by *Melia dubia* (30.41 t ha^{-1}). Significantly lower soil organic carbon stock was found in *Madhuca latifolia* (24.12 t ha^{-1}). The total soil organic carbon stock varied significantly depending on region, species, soil quality and previous land-use pattern. *Pongamia pinnata* and *Melia dubia* accumulated considerable quantity of soil organic carbon because of litter fall, fast decomposition rate and vigorous growth. These results are in accordance with Ahmedin *et al.* (2013) and Dhyani *et al.* (2016).

Based on the performance of growth and yield traits analysis, *Melia dubia* recorded significantly higher tree height (12.72 m), DBH (38.61 cm), wood volume (0.848 m^3), canopy spread (13.78 m in N-S and 12.18 m in S-W direction) and average seed yield of 28.1 kg/ha as against other tree species. The performance of *Simarouba glauca, Azadirachta indica and Pongamia pinnata* was better compared to *Calophyllum inophyllum* and *Madhuca latifolia* whose growth and yield was poor. The average seed yield of *Simarouba glauca, Azadirachta indica and Pongamia pinnata* was found to be 24.5, 19.7 and 32.5 kg/ha respectively.

Th\e above ground (67.64 t ha^{-1}), below ground (17.63 t ha^{-1}) and total biomass of tree (85.47 t ha^{-1}) was significantly higher in *Melia dubia* as against other tree species. The total tree biomass of *Azadirachta indica* and *Simarouba glauca* was comparatively better than *Calophyllum inophyllum* whose total biomass was very low. Hence, *Melia dubia* was able to sequester more carbon i.e., 42.73 t ha^{-1} which is equal to 156.8 tonnes of CO_{2--}. *Azadirachta indica* sequestered 16.4 t ha^{-1} which amounts to 60.2 tonnes of CO_{2--} and *Simarouba glauca* sequestered 15.61 t ha^{-1} which amounts to 57.3 tonnes of CO_{2--}. The soil organic carbon stock was significantly high in *Pongamia pinnata* which recorded 31.35 t ha^{-1} which is equal to 115 tonnes of CO_2.

TABLE 5

Total biomass and carbon sequestration of different tree borne oilseed species established at UAS, GKVK campus, Bengaluru

Tree species	Above ground biomass (t ha^{-1})	Below ground biomass (t ha^{-1})	Total tree biomass (t ha^{-1})	Tree carbon stock (t ha^{-1})	Soil organic carbon stock (t ha^{-1})
Simarouba glauca	24.79	6.44	31.23	15.61	28.67
Melia dubia	67.84	17.63	85.47	42.73	30.41
Azadirachta indica	26.04	6.77	32.81	16.40	26.73
Melia azedarach	19.09	4.97	24.05	12.02	27.47
Pongamia pinnata	15.34	3.98	19.32	9.66	31.35
Madhuca latifolia	14.46	3.76	18.22	9.11	24.12
Calophyllum inophyllum	1.93	0.50	2.43	1.21	25.33
S.Em±	0.72	0.19	0.91	0.46	0.72
CD at 5%	2.23	0.58	2.81	1.40	2.24

In a nutshell, *Melia dubia* was able to sequester 268.4 tonnes of CO_2 followed by *Simarouba glauca* which sequestered 162.5 tonnes of CO_2 and *Pongamia pinnata* which captured 150.5 tonnes of CO_2. This indicated that *Melia dubia, Simarouba glauca* and *Pongamia pinnata* were highly promising tree species for carbon sequestration over other tree species.

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