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The carbon stock in vegetation under wheat and *Eucalyptus tereticornis* based: Agroforestry system

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Abstract

A field experiment was conducted to know about the carbon stock by trees and associated underground vegetation under eucalyptus based-agroforestry system RBD design with three replications during 2016-17 and 2017-18 at farmer field of Jabalpur. The result showed that the weed control treatments increase the crop biomass production and minimize the biomass of weeds. The hand weeding found higher carbon stock 4.26 and 3.83 t/ha and lower in weedy check during both the year in wheat crop. When weeds are growing without restriction it stored 1.18 and 1.19 t C/ha during both the year. The eucalyptus stored 53.17 to 55.75 and 68.05 to 71.41 t carbon/ha during 2016-17 and 2017-18, respectively. The agroforestry system found higher carbon stock 17.18 to 18.24 and 17.13 to 18.16 t/ha yr^{-1} as compared to crop alone 4.26 and 3.83 t/ha yr^{-1} under Wheat and *Eucalyptus tereticornis* based-Agroforestry system.

Keywords: Wheat, weed, agroforestry, carbon stock

Introduction

Agricultural land is thought to be a major sink of CO_2 and could absorb large amounts of CO_2 (C) if it is planted with trees and carefully managed with crops or/or animals. Tree-based-land use, forest plantation, and agro-forestry systems sequester CO_2 because of the storage capacity of carbon in their biomass. By promoting agro-forestry systems with higher carbon content than mono plant community, can realize net gains in carbon stock (i.e. sequestration). Agroforestry is becoming more recognized as a land use strategy not only for agricultural sustainability but also for climate change issues. It has carbon storage potential in many plant species and soil types as well as applicability in agricultural land and reforestation. The potential for agroforestry is immense; it has not yet been adequately recognised, l*et al*one exploited.

Carbon in the form of CO_2 is currently being released into the atmosphere at an average of 3.5 billion tonnes per year due to fossil fuel combustion, deforestation in tropical areas and forest fuel combustion. Agroforestry systems can be a better climate change mitigation solution compared to ocean and other terrestrial options. The secondary environmental benefits of agroforestry include food security, secured land tenure, increased farm income, restoration and maintenance of biodiversity above and below ground, conservation of watershed hydrology, soil

Adding trees to agricultural production systems increases the carbon sequestration potential of land dedicated to agriculture while allowing food crops to be grown. The average carbon sequestration potential in agro-forestry is $25tCh^{-1}$ across 96 million ha of land in the Indian subcontinent. Watson *et al*. (2000) [16], estimated carbon gain at 0.72 mg C h^{-1} h^{-1} y on 4000 m ha of agri cropped land, with a potential to sequester 26 tg C h yr^{-1} in 2010 and 45 tg C hyr^{-1} in 2040. The purpose of this study is to assess the potential for carbon sequestration in agro-forestry systems by various weed management practices.

Materials and Methods

This field investigation are examined at rabi season 2016-17 and 2017-18 at farmers farm land of Jabalpur. The wheat are intercropped with 4 years old *Eucalyptus tereticornis* trees with plant distance of 3 m X 1.5 m. The treatment of weed management practice consisted of 2, 4-D @ 0.5 lit/ha, Metribuzin @ 0.250 Kg ha^{-1}, Butachlor @ 1 lit/ha, Clodinafop-propargyl @ 0.140 kg/ha, 2, 4-D @ 0.5 lit/ha *fb* metribuzin @ 0.250 Kg/ha, 2, 4-D @ 0.5 lit/ha *fb* butachlor @ 1 lit/ha, Metribuzin @ 0.250 Kg/ha *fb* butachlor @ 1 lit/ha, 2, 4-D @ 0.5 lit/ha+ hand weeding at 30 DAS, Hand Weeding at 30 DAS and Weedy check. The herbicides and weeding treatments applied at 30 DAS as post emergent in tellering stage.

Estimation of aboveground fresh biomass
The average of 30 trees in each replication eucalyptus trees was used in mean DBH and tree hight were taken and nearly mean tree felled at ground level. The each part of felled tree *viz.*, leaves, bark, twigs, branch and bole with or without bark and fresh weight of each part was recorded immediately with spring balance.

Sampling for analysis of dry oven mass
The fresh weight sample of tree component was put in hot air oven. For stem sample, after 3.5 m bole 3 discs of 10 cm length was taken. Whereas, the 0.5 kg sample of leaf, branch and bark was tied in poly bag to reduce evaporation. All samples of tree parts were kept in oven at 65 °C for 24 hours. The oven dried weight is recorded and converted into dried mass on hectare basis. The sum of leaf, bark, twings, branch and bole biomass was used in above ground tree biomass.

Sample of wheat and weed biomass (t/ha)
Crop biomass was counted by quadrate methods at harvesting time. The crop and weed biomass of the quadrate were cut at ground level and collected samples was weighted and oven dried at 60 ± 5^0C to a constant weight.

Belowground biomass of trees (Kg ha^{-1})
The factor of root: shoot ratio (0.26) is used in calculation of belowground biomass. (Hangarge *et al.*, 2012) [5].

Belowground biomass = above ground biomass x 0.26

Total Biomass (Kg ha^{-1})
The sum of above and below ground biomass is used as total biomass (Sheikh *et al.* 2011) [15].

Total Biomass (TB) = Aboveground Biomass + Belowground Biomass

Carbon stock studies
Ash percent (%): The ash method is used in carbon in plant biomass. The 5 gm oven dried sample was taken in pre weighed crucible and sample put in dessicator and cooled slowly inside. After cooling the crucible with ash was weighed and organic carbon was counted as formula given by Allen *et al.* (1986) [2].

Ash content (%)

$$\text{Ash (\%)} = \frac{W3 - W1}{W2 - W1} \times 100$$

Carbon percent (%)
C (%) = (100- Ash %) x 0.58

(Considering 58% carbon in ash-free litter material)

Where,
C = Organic carbon
W1 = Weight of crucibles
W2 = Weight of oven dried grind samples with crucible
W3 = Weight of ash with crucible

Carbon stock (t/ha)
Carbon percent content was multiplied by dry biomass to give carbon stock as per the formula suggested by Rajput (2010) [11].

Carbon stock = dry biomass x Carbon content

Results and Discussion
Aboveground biomass of tree (t/ha)
The aboveground biomass production of tree between 80.02 to 82.12 t/hawas found during 2016-17 at the age of 4th year and 101.26 to 105.27 t/haat the age of 5th year 2017-18 under wheat-*Eucalyptus tereticornis* based-agroforestry system (Table 1).

Belowground biomass of tree (t/ha)
The total belowground biomass between 20.80 to 21.35 t/ha and from 26.33 to 27.37 t/hawas found during 4th and 5th year of experiment of *Eucalyptus tereticornis* (Table 1).

Total biomass production (Aboveground + belowground) (t/ha)
The total biomass of tree found between 100.82 to 103.48 t/ha and 127.59 to 132.13 t/ha during both the year of experiment. (Table 1).

Wheat biomass (t/ha)
The maximum biomass (above + below ground) of wheat was found in hand weeding 8.35 and 7.30 t/ha during both of the experimental year which was lower in weedy check. (Table 1).

Weed biomass (t/ha)
The higher weed biomass (above + below ground) was found in weedy check 2.29 and 2.25 t/ha during both the year. (Table 1).

Total Biomass production (tree and/or agriculture crops) (t/ha)
The hand weeding at 30 DAS found higher total biomass production (39.71 and 39.21 t/ha during both the experimental year, respectively) (Table 1).
The production of above and below ground biomass in agroforestry system influence by different factors *viz.*, tree and crops combination, growth pattern of tree and crops, genetics trait of trees and crops, quality of site, soil type, tree age, tending operations, moisture conservation, allelopathy tree, water, light and space competition and many other factors influence above and below ground biomass production. This study was also suggested by several experimenters *viz.*, Lott *et al*. (2002) [6], Sanneh (2007) [13], Chauhan *et al*. (2009) [3], Rizvi *et al*. (2011) [12], Mangalassery *et al*. (2014) [7]. Puri *et al*. (2002) [10] suggested that the total biomass accumulation in *Populus deltoids* based-agroforestry varied from 41 to 206 Mg ha^{-1} and agroforestry have highest as compared to sole.

Carbon stock study (t C/ha)
Carbon stock from Wheat biomass
Aboveground Carbon stock (t C/ha)
The aboveground carbon stock was higher in hand weeding at 30 DAS over all weed control treatment and weedy check during both years of experiments. The weed control methods accumulate higher biomass carbon varied from 2.54 to 3.42 t C/ha and 2.23 to 3.08 t C/ha during both of the experimental year over weedy (Table 2).

Belowground carbon stock (t C/ha)
The carbon storage in below ground higher under hand weeding at 30 DAS (0.83 and 0.75 t C/ha during both the year, respectively) over weedy check (0.58 and 0.45 t C/ha respectively). (Table 2).

Total carbon stock by wheat (t C/ha)
The weed control treatments have visible on carbon stock from wheat biomass. The total carbon stock was significantly higher under hand weeding at 30 DAS (4.26 and 3.83 t C/ha during 2016-17 and 2017-18, respectively) over weedy check. The rest of the weed control treatments were also gave higher total carbon stock over weedy check during both the year (Table 2).

Carbon stock from Weed biomass (t C/ha)
Aboveground carbon stock (t C/ha)
Aboveground carbon stock was significantly higher under weedy check (0.95 and 0.97 t/haduring 2016-17 and 2017-18, respectively) over hand weeding at 30 DAS (0.13 and 0.04 t C/ha during 2016-17 and 2017-18, respectively). The different weed control treatments have had lower carbon stock during first and second year over weedy check (Table 2).

Belowground carbon stock (t C/ha)
The weed control treatments have significant influence on carbon stock in weed biomass. The belowground carbon stock was significantly higher under weedy check (0.23 and 0.22 t C/ha during 2016-17 and 2017-18, respectively) over hand weeding at 30 DAS during both the year. The weed control treatment was given lower belowground carbon stock over weedy check. The weed management practices was found lower IN below ground carbon stock over weedy check under wheat-*Eucalyptus tereticornis* based-agroforestry system (Table 2).

Total carbon stock in weed (t C/ha)
The weedy check treatment found superior carbon stock (1.18 and 1.19 t C/ha during 2016-17 and 2017-18, respectively) over all weed management methods due to higher biomass of weed during both the year. (Table 2).

Carbon stock from Tree biomass
Aboveground carbon stock (t C/ha)
The eucalyptus tree store carbon between 42.15 to 44.13 t C/ha at agroforestry system during first year of experiment and during second year 53.91 to 57.89 t C/ha was stored total above ground carbon under wheat-*Eucalyptus tereticornis* based-agroforestry system (Table 3).

Belowground carbon stock (t C/ha)
The belowground carbon stock of eucalyptus tree range between 11.02 to 11.62 t C/ha and 14.14 to 15.21 t C/ha was found under during first and second year of experiments. (Table 3).

Total carbon stock (t C/ha)
Eucalyptus tree at the age of 4th year 53.17 to 55.75 t C/ha and at the age of 5th year 68.05 to 73.10 t C/ha was stored under wheat-*Eucalyptus tereticornis* based-agroforestry system with different weed management practices. (Table 3).

Vegetation carbon stock (tree and/or agriculture crops) (t C/ha Yr^{-1}): The aboveground and belowground vegetation carbon storage found between 13.66 to 14.50 and 3.52 to 3.74 t C/ha yr^{-1} during 2016-17 and 13.60 to 14.44 and 3.50 to 3.72 t C/ha yr^{-1} above and below ground carbon storage during 2017-18 second year of experiment. The agroforestry system have stored total carbon between 17.18 to 18.24 and 17.13 to 18.16 t C/ha at two year of experiment under wheat-*Eucalyptus* based-agroforestry system (Table 4). We can say by above result that, the carbon storage of different cropping pattern is depend in ash content. The ash content higher in complex structural components. More the complex tissue maximum ash percent it also based-on components nature (tree and crops), density of crop, growth charectors, genetic parameters, age, tending operations and many other. Albrecht and Kandaji (2003) [1] suggested that carbon storage variability in tree biomass can be high among complex systems and productivity was influenced by number of factors including component nature, properties of soil and the system management. Chauhan *et al*. (2015) [4], and Mangalassery *et al*. (2014) [7], Prasad *et al*. (2012) [9].

Table 1: Total biomass production under wheat- *Eucalyptus tereticornis*- based agroforestry system

	Treatment	Tree biomass production (t/ha)						Wheat biomass (t/ha)		Weed biomass (t/ha)		Biomass Production (t/hayr^{-1})	
		Aboveground		Belowground		Total							
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D @ 0.5 lit/ha	80.47	104.19	20.92	27.09	101.40	131.28	7.13	5.84	0.55	0.49	38.21	37.96
T_2	Metribuzin @ 0.250 Kg ha^{-1}	81.13	105.27	21.09	27.37	102.22	132.63	7.19	5.94	0.76	0.57	38.73	38.46
T_3	Butachlor @ 1 lit/ha	80.02	101.66	20.80	26.43	100.82	128.09	6.19	5.23	1.07	0.79	37.62	36.87
T_4	Clodinafop-propargyl@ 0.140 kg ha^{-1}	80.07	101.83	20.82	26.48	100.89	128.31	7.43	6.39	1.08	0.81	38.88	38.10
T_5	2, 4-D @ 0.5 lit/ha *fb* metribuzin @ 0.250 Kg ha^{-1}	81.42	101.46	21.17	26.38	102.59	127.84	6.89	6.03	0.53	0.44	38.29	37.26
T_6	2, 4-D @ 0.5 lit/ha *fb* butachlor @ 1 lit/ha	82.03	102.74	21.33	26.72	103.36	129.46	6.67	5.81	0.90	0.67	38.68	37.66
T_7	Metribuzin @ 0.250 Kg/ha *fb* butachlor @ 1 lit/ha	81.00	105.10	21.06	27.33	102.06	132.43	6.49	5.25	1.08	0.84	38.29	38.00
T_8	2, 4-D @ 0.5 lit/ha+ hand weeding at 30 DAS	81.59	104.47	21.21	27.16	102.80	131.63	7.12	5.87	0.56	0.50	38.62	38.08
T_9	Hand Weeding at 30 DAS	81.90	104.86	21.30	27.27	103.20	132.13	8.35	7.30	0.30	0.09	39.71	39.21
T_{10}	Weedy check	82.12	101.26	21.35	26.33	103.48	127.59	5.84	4.42	2.29	2.25	39.27	37.40
S.Em±		1.24	1.07	0.32	0.28	1.56	1.35	0.13	0.30	0.10	0.07	0.48	0.38
CD (P=0.05)		3.62	3.14	0.94	0.82	4.56	3.95	0.37	0.86	0.29	0.22	1.39	1.12

Table 2: Carbon stock in wheat and weeds biomass under wheat- *Eucalyptus tereticornis* -based agroforestry system

	Treatment	Carbon stock from wheat biomass (t C/ha)						Carbon stock in weed biomass (t C/ha)					
		Aboveground		Belowground		Total		Aboveground		Belowground		Total	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D @ 0.5 lit/ha	2.94	2.48	0.71	0.60	3.65	3.08	0.23	0.21	0.06	0.05	0.29	0.26
T_2	Metribuzin @ 0.250 Kg ha^{-1}	2.95	2.53	0.72	0.61	3.67	3.15	0.32	0.24	0.08	0.05	0.40	0.30
T_3	Butachlor @ 1 lit/ha	2.54	2.23	0.62	0.54	3.15	2.77	0.45	0.34	0.11	0.08	0.55	0.41
T_4	Clodinafop-propargyl@ 0.140 kg ha^{-1}	3.05	2.72	0.74	0.66	3.80	3.38	0.45	0.34	0.11	0.08	0.56	0.42
T_5	2, 4-D @ 0.5 lit/ha *fb* metribuzin @ 0.250 Kg ha^{-1}	2.81	2.55	0.68	0.62	3.49	3.17	0.22	0.19	0.05	0.05	0.27	0.24
T_6	2, 4-D @ 0.5 lit/ha *fb* butachlor @ 1 lit/ha	2.72	2.46	0.67	0.60	3.39	3.05	0.37	0.28	0.09	0.07	0.46	0.35
T_7	Metribuzin @ 0.250 Kg/ha *fb* butachlor @ 1 lit/ha	2.65	2.23	0.65	0.54	3.30	2.77	0.45	0.36	0.11	0.08	0.55	0.44
T_8	2, 4-D @ 0.5 lit/ha+ hand weeding at 30 DAS	2.90	2.51	0.71	0.61	3.61	3.12	0.23	0.22	0.05	0.05	0.29	0.27
T_9	Hand Weeding at 30 DAS	3.42	3.08	0.83	0.75	4.26	3.83	0.13	0.04	0.03	0.01	0.16	0.05
T_{10}	Weedy check	2.36	1.88	0.58	0.45	2.94	2.33	0.95	0.97	0.23	0.22	1.18	1.19
S.Em±		0.06	0.12	0.01	0.03	0.07	0.15	0.04	0.03	0.01	0.01	0.05	0.04
CD (P=0.05)		0.17	0.35	0.04	0.09	0.22	0.44	0.12	0.10	0.03	0.02	0.15	0.12

Table 3: Carbon stock in tree biomass under wheat- *Eucalyptus tereticornis*- based agroforestry system

	Treatment	Carbon stock in tree biomass (t C/ha)					
		Aboveground		Belowground		Total	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D @ 0.5 lit/ha	42.15	56.21	11.02	14.72	53.17	70.93
T_2	Metribuzin @ 0.250 Kg ha^{-1}	42.94	57.89	11.23	15.21	54.17	73.10
T_3	Butachlor @ 1 lit/ha	42.69	55.17	11.22	14.58	53.91	69.75
T_4	Clodinafop-propargyl @ 0.140 kg ha^{-1}	42.58	54.56	11.15	14.31	53.73	68.86
T_5	2, 4-D @ 0.5 lit/ha *fb* metribuzin @ 0.250 Kg ha^{-1}	43.18	55.25	11.32	14.51	54.51	69.77
T_6	2, 4-D @ 0.5 lit/ha *fb* butachlor @ 1 lit/ha	44.01	54.90	11.56	14.42	55.57	69.33
T_7	Metribuzin @ 0.250 Kg/ha *fb* butachlor @ 1 lit/ha	42.81	57.14	11.17	15.03	53.98	72.17
T_8	2, 4-D @ 0.5 lit/ha+ hand weeding at 30 DAS	42.87	55.24	11.22	14.49	54.08	69.72
T_9	Hand Weeding at 30 DAS	43.79	56.59	11.50	14.82	55.30	71.41
T_{10}	Weedy check	44.13	53.91	11.62	14.14	55.75	68.05
S.Em±		1.06	1.13	0.30	0.32	1.36	1.45
CD (P=0.05)		3.10	3.30	0.87	0.94	3.96	4.24

Table 4: Carbon stock in (tree and/or agriculture crops) biomass under wheat- *Eucalyptus tereticornis*- based agroforestry system

	Treatment	Carbon stock from vegetation biomass (t C/ha yr^{-1})					
		Aboveground		Belowground		Total	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	2, 4-D @ 0.5 lit/ha	13.71	13.94	3.52	3.59	17.23	17.53
T_2	Metribuzin @ 0.250 Kg ha^{-1}	14.01	14.35	3.60	3.71	17.61	18.06
T_3	Butachlor @ 1 lit/ha	13.66	13.60	3.53	3.53	17.18	17.14
T_4	Clodinafop-propargyl @ 0.140 kg ha^{-1}	14.15	13.97	3.64	3.60	17.79	17.57
T_5	2, 4-D @ 0.5 lit/ha *fb* metribuzin @ 0.250 Kg ha^{-1}	13.82	13.79	3.57	3.57	17.39	17.36
T_6	2, 4-D @ 0.5 lit/ha *fb* butachlor @ 1 lit/ha	14.10	13.72	3.65	3.55	17.75	17.27
T_7	Metribuzin @ 0.250 Kg/ha *fb* butachlor @ 1 lit/ha	13.80	14.02	3.55	3.63	17.35	17.65
T_8	2, 4-D @ 0.5 lit/ha+ hand weeding at 30 DAS	13.85	13.78	3.56	3.56	17.41	17.33
T_9	Hand Weeding at 30 DAS	14.50	14.44	3.74	3.72	18.24	18.16
T_{10}	Weedy check	14.34	13.63	3.71	3.50	18.06	17.13
S.Em±		0.27	0.22	0.07	0.06	0.34	0.28
CD (P=0.05)		0.77	0.64	0.21	0.18	0.99	0.81

Conclusion

The system of agroforestry stored higher carbon due to agricultural crops, weeds and tree components by there higher biomass accumulation than single component. The weed management practices increased the wheat biomass, whereas weedy check showed higher weed biomass. The total biomass production was higher in hand weeding 30 DAS (39.71 and 39.21 t/ha) during both of the experimental year. The total vegetation carbon storage of agroforestry system observed 17.18 to 18.24 and 17.13 to 18.16 t C/ha yr^{-1} was found during 2016-17 and 2017-18 under wheat-*Eucalyptus tereticornis*-based agroforestry system.

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