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Carbon Sequestration in a Agroforestry system at Kurukshetra in Northern India

Mohit Kumar

Assistant Professor, Department of Environmental Science,
Guru Nanak Khalsha College, Yamuna Nagar, Haryana, INDIA

(Corresponding author: Mohit Kumar)

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ABSTRACT: Estimation of vegetation and soil carbon stocks of *Mangifera indigca* plantation under agroforestry in Kurukshetra, Haryana in Northern India was carried out from January to April 2015. The agroforestry system selected for study at Kurukshetra is characterized by *Mangifera indica.* The wheat (*Triticum aestivum*) crop was grown in interspaces between the rows of plantation trees in 12 yr old agroforestry system. The aboveground biomass was 77.37 % of the total biomass. There was large biomass in trees of *Mangifera indica* trees which amounted to 263.30 Mg ha^{-1} above ground and 79.23 Mg ha^{-1} belowground which was 22.74% of the total biomass. In the agroforestry system. The soil organic carbon content at 0-15 cm soil depth was 17.352 Mg ha^{-1} and 10.706 Mg ha^{-1} at 15-30cm soil depth. The above ground carbon content of agroforestry was 131.65 Mg ha^{-1} and belowground carbon content was 39.61 Mg ha^{-1} . The total carbon stock at the time of study was 175.792 Mg ha^{-1}.

Keywords: Carbon sequestration, Biomass, Agroforestry, Soil organic carbon

I. INTRODUCTION

Climate change is among the major global issues of the 21st century. Anthropogenic activities have led to notable changes in the earth's climate including increase in the global temperature, increase in frequency of extreme events and heavy precipitation. The rise in global temperatures has been attributed to emission of greenhouse gasses (GHG), notably CO_2.

Agroforestry provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation. Although agroforestry systems are not primarily designed for carbon sequestration, there are many recent studies that substantiate the evidence that agroforestry systems can play a major role in storing carbon in aboveground biomass and in soil and in belowground biomass. Agroforestry, the practice of introducing trees in farming has played a significant role in enhancing land productivity and improving livelihoods in both developed and developing countries. Although carbon sequestration through afforestation and reforestation of degraded natural forests has long been considered useful in climate change mitigation, agroforestry offers some distinct advantages. The planting of trees along with crops improves soil fertility, controls and prevents soil erosion, controls water logging, checks acidification and eutrophication of streams and rivers, increases local biodiversity, decreases pressure on natural forests for fuel and provides fodder for livestock. It also has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change. The effectiveness of agroforestry systems in storing carbon depends on both environmental and socio-economic factors; in humid tropics, agroforestry systems have the potential to sequester over 70 Mg/ha in the top 20 cm of the soil. The carbon storage capacity in agroforestry varies across species and geography. According to the IPCC report agroforestry systems offer important opportunities of creating synergies between both adaptation and mitigation actions with a technical mitigation potential of 1.1-2.2 PgC in terrestrial ecosystems over the next 50 years (IPCC 2001). Additionally, 630 Mha of unproductive croplands and grasslands could be converted to agroforestry representing a carbon sequestration potential of 391,000 MgC/yr by 2010 and 586,000 MgC/yr by 2040 (IPCC 2007).

Objective: To estimate the total biomass accumulation in agroforestry (*Mangifera indica + Triticum aestivum*) system at Kurukshetra.

To estimate the carbon sequestration in agroforestry (*Mangifera indica + Triticum aestivum*) system.

II. METHODOLOGY

To estimate biomass of different trees, non-destructive method was used. DBH (Diameter at Breast Height) can be determined by measuring tree Girth at Breast Height (GBH), approximately 1.3 meter from the ground. The GBHs of trees having diameter greater than 10 cm were measured directly by measuring tape.

A. Volume equations for estimation of biomass and carbon content

Direct tree harvest data are difficult to obtain so allometric equations are used for tree species and for the diameter above 10 cm at breast height.

B. Volume Equations used for Mangifera indica species are as follows:

AGB = V/D^2 = $-0.00342/D^2-0.0922/D + 2.28178 + 9.46641*D$

BGB = exp (-1.0587 + 0.8836*ln AGB)

And wood specific gravity = 0.55

C. Soil Sampling

The soil samples in the present study were collected from each plantation (12 yr to 15 yr old) by inserting soil corer at two depth, viz. 0-15, 15-30 cm in February and March of 2015. The pH of the soil was determined by digital pH meter and organic carbon was determined by wet –oxidation method.

III. RESULTS AND DISCUSSION

A. Soil Characteristics

Table 1: Soil pH, bulk density, Organic carbon and Inorganic carbon of the different soil samples taken from different depth.

System	Soil Depth (cm)	Soil pH	Bulk Density ($g.cm^3$)	Organic Carbon %	Inorganic Carbon %
Wheat	0-15	7.64	1.20	0.794	0.202
Wheat	15-30	7.78	1.26	0.524	0.256
W+MI	0-15	7.8	1.32	0.876	0.169
W+MI	15-30	7.8	1.39	0.514	0.205

From the results given in Table 1, it is clear that soil Ph varied from 7.64 to 7.8 across soil depth. The bulk density of soil in sole cropping was 1.20 to 1.26 g cm^{-3}. In the agroforestry system, the bulk density of soil ranged from 1.32 to 1.39 g cm^{-3}. The soil organic carbon concentration at 0-15 cm soil depth was 0.794% and was 0.524% at 15-30cm soil depth. In the agroforestry system. The soil organic carbon concentration at 0-15 cm soil depth was 0.876% and was 0.514% at 15-30cm soil depth. The soil inorganic carbon concentration in soil varied from 0.167 to 0.256% across soil depths.

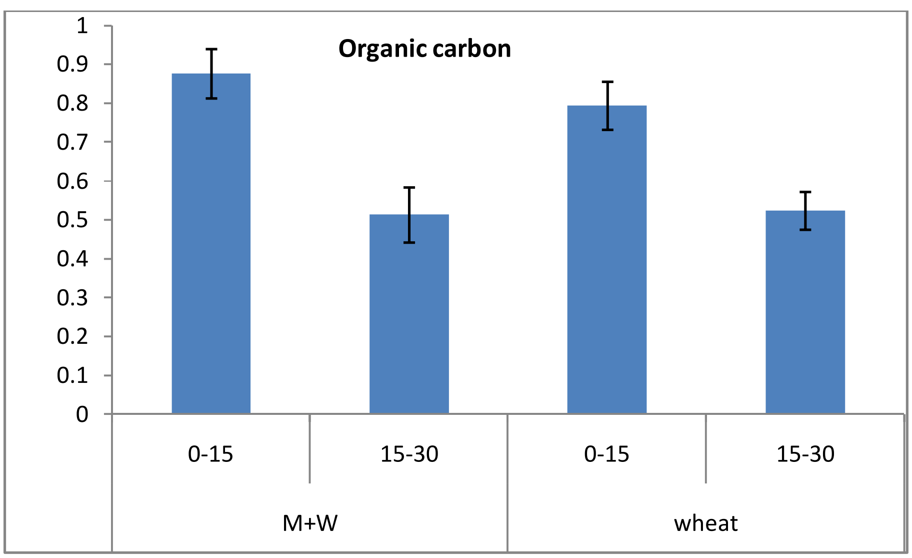

Fig. 1. The organic carbon (%) in the soil at different depth in the Agroforestry (Mango + Wheat) and Agriculture system.

From the Fig. 1, it is clear that O.C (%) is decreases with soil depth. The O.C of the M+W sample at 0-15 cm depth is 0.876 % and at 15-30cm it is 0.513 % whereas in sample wheat only at 0-15cm depth O.C(%) is 0.794 % and at 15-30cm it is 0.523%. This difference is due to the trees in agrogorestry which provide organic matter to the soil whereas trees are not percent in the agriculture so have less organic carbon content.

Table 2: Biomass of cropping and the agroforestry system.

	Total biomass (Mg ha^{-1})		
Plant component	**(Wheat system)**	**Trees**	**(W+MI)**
Aboveground Biomass	10.010	263.30	273.31
Belowground Biomass	0.700	79.23	79.93
Total Biomass	10.71	342.53	353.24

Table 3: Carbon pool in soil in the agroforestry and wheat cropping systems.

	Carbon pool (Mg ha^{-1})			
	Organic pool		**Inorganic pool**	
Soil depth	**Agriculture (wheat system)**	**Agroforestry (W+MI)**	**Agriculture (wheat system)**	**Agroforestry (W+MI)**
(0-15) cm	15.487	17.352	3.342	3.939
(15-30)cm	10.684	10.706	4.278	5.222
Total	26.171	28.058	7.62	9.161

Carbon storage potential of agroforestry system in different eco-regions of the world is given Table 4. The carbon sequestration potential varied from 12-228 MgC/h in Southeast Asia agroforestry systems. The carbon sequestration potential of 175.792 MgC/h found in this study was found to be comparable to the Agrosilvicultural systems of North America and Southeast Asia.

The carbon in the aboveground and belowground biomass in an agroforestry system is generally much higher than the equivalent land use without trees (i.e. crop land without any trees). The estimates of potential for carbon storage in different kinds of agroforestry systems are done (Albrecht and Kandji 2003). In Southeast Asia, agrisilvicultural systems have the capacity to store 12-228 MgC/ha in humid tropical lands and 68-81 MgC/ha in dry lowlands. Highest potential for carbon storage can be observed for North American silvi pastoral systems with a range of 90-198 MgC/ha. The potential to sequester carbon in aboveground components in agroforestry systems is estimated to be 2.1×109 MgC $year^{-1}$ in tropical and 1.9×109 MgC $year^{-1}$ in temperate biomes. Agroforestry systems can have indirect effects on carbon sequestration as it helps decrease pressure on natural forests that are the largest sinks of terrestrial carbon, they also conserve soils and thus enhance carbon storage in trees and soils. Effects of agroforestry practices on the soil carbon pool indicated a rate of increase by 2-3 MgC/ha/yr.

Table 4: Carbon storage potential of agroforestry system in different eco-regions of the world.

Continent	Eco-region	System	Carbon seq. potential (MgC/h)
Africa	Humid tropical high	Agrosilvicultural	29-53
South America	Humid tropical low dry low lands	Agrosilvicultural	39-102 39-195
Southeast Asia	Humid tropical dry low lands	Agrosilvicultural	12-228
Australia	Humid tropical low	Silvopastoral	28-51
North America	Humid tropical high humid tropical low dry lowlands	Silvopastoral	104-198 90-175
North Asia	Humid tropical low	Silvopastoral	15-18
Gulabgarh Kurukshetra North India	Semiarid	Agrosilvicultural	175.792

IV. CONCLUSION

The agroforestry systems selected for study at Kurukshetra is characterized by *Mangifera indica.* The wheat (*Triticum aestivum*) crop was grown in interspaces between the rows of plantation trees in 12 yr old agroforestry system. The biomass accumulation in the wheat system was 10.01 Mg ha^{-1} based on data from Devi *et al* (2013). The aboveground and belowground biomass ratio was 14.4. The aboveground biomass was 77.37 % of the total biomass. There was large biomass in trees of *Mangifera indica* trees which amounted to 263.30 Mg ha^{-1} aboveground and 79.23 Mg ha^{-1} belowground. The belowground biomass was 22.74 % of the total biomass.

In Agricultural system, the soil organic carbon content at 0-15 cm soil depth was 15.487 Mg ha^{-1} and was 10.684 Mg ha^{-1} at 15-30cm soil depth. In the agroforestry system, The soil organic carbon content at 0-15 cm soil depth was 17.352 Mg ha^{-1} and was 10.706 Mg ha^{-1} at 15-30cm soil depth. The aboveground carbon content of agroforestry was 131.65 Mg ha^{-1} that is higher than the agriculture system which is 4.220 Mg ha^{-1} and belowground carbon content of agroforestry was 39.615 Mg ha^{-1} that is also higher than the agriculture system that is 4.527 Mg ha^{-1}.

From the results it evident that integrating trees with the crops substantially increased total biomass production. The carbon sequestration potential in the trees and soil increased in the agroforestry. Thus agroforestry was found to be a sustainable land use system for improving biological productivity and carbon sequestration. Keeping in view the role of agroforestry in carbon sequestration, these systems can play an important role in climate change mitigation and adaptation.

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