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Carbon sequestered through biomass and soil organic carbon dynamics in *Jatropha curcas* L.

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ABSTRACT

Revegetation of degraded land is a big challenge in present scenario where per capita land availability is reducing drastically. According to the latest estimates about 187.8 mha (57% approximately) out of 328.73 mha land has been degraded in India. *Jatropha curcas* L. (Jatropha) known as a bio fuel plant, is suitable for revegetation of degraded land. However, soil organic carbon (SOC) dynamics under Jatropha plantations are still not well understood. The objective of this study was to quantify soil organic carbon (SOC) and carbon sequestration potential under two-year-old Jatropha plantation spread over 300 hectares, at Barkaccha, Rajiv Gandhi South Campus (BHU), Mirzapur, Uttar Pradesh, India. Soil samples were collected periodically at three month interval (January and April) from the two soil depths i.e. 0-15 and 15-30 cm. In this study, instead of the more popular diameter at breast height (DBH), collar diameter (diameter at stem base) was used because the stem of *Jatropha* hardly grew at DBH level. The total plant biomass (leaves, branches and coarse roots) was quantified by multiplying the average dry biomass of one individual by the number of trees per hectare. Carbon sequestered in January and April for aboveground dry biomass were 0.85 and 0.93 t/ha and for belowground dry biomass were 0.17 and 0.19 t/ha. These results revealed that the potential of carbon sequestration in Jatropha was higher as found in crops and can be adopted to reclaim waste land and to mitigate climate change.

Key words: *Carbon stock, Jatropha curcas, Biomass accumulation,* CO_{2-e} *and soil organic carbon (SOC)*

Introduction

Land degradation along with deterioration of soil health is mainly influenced by perturbation in biogeochemical cycle. Once this fragile cycle interrupted many negative environmental consequences occurred. Global warming is amongst the most dreaded problems of the new millennium. Carbon emission is supposedly the strongest causal factor for global warming. So, increasing carbon emission is one of today's major concerns, which is well addressed in Kyoto protocol. The models referenced by the Inter-governmental Panel on Climate Change (IPCC) have predicted that global temperatures are likely to increase by 1.1°C to 6.4°C between 1990 and 2100. Climate change, for the poor in particular, will make matters worse, particularly if populations remain uneducated and no technological or methodological breakthroughs break through the politics (Mozejko 2009). With the ecological crisis that can be foreseen in the 21st century due to a rapidly expanding population in many countries, rapidly decreasing natural resources in all countries and significant global climate changes, there will be a growing need

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for ecological modelling (Jorgensen 2009).The data generated in this experiment may be used for claiming carbon credits and developing models for better estimation of sequestered carbon.

Sustainable energy production and supply are strategic objectives for developed as well as developing countries. Revegetation of degraded land is a big challenge. There may seem to be a great amount of marginal land in developing countries that is not being used and where Jatropha could be grown. This study investigates the carbon sequestration capacity of Jatropha curcas, a tropical tree-like shrub that is often cultivated for the production of oilseeds for biodiesel and bio kerosene. So far, the carbon sequestration function of Jatropha trees has received much less attention than its oilseed production potential, but there is a growing interest in exploiting its potential carbon sequestration services. Moreover, the carbon sequestration capacity of Jatropha shrubs is an essential determinant of the overall greenhouse gas reduction performance of its biofuel (Bailis and McCarthy 2011). The question how much dry biomass is accumulated in a *Jatropha curcas* tree was addressed by Benge (2006); Reinhardt *et al.* (2008); Francis *et al.* (2005); Struijs (2008). However, these early publications were based on rough estimations or unverifiable sources and unclear methods. Destructive research, in which the weight of a Jatropha tree is determined by digging out and actually weighing the tree, would give a more accurate idea of the biomass that is produced in a Jatropha tree. Assimilated CO_2 in plant biomass will in turn be transformed into stable organic matter (i.e. humus) after litterfall and sloughed root decomposition in the soil returning converted CO_2 in the form of carbon (C) to soil (Firdaus *et al.* 2010).

Materials and Methods

Study site

Present study was carried out in Mirzapur district (Uttar Pradesh, India) at Rajiv Gandhi South Campus (BHU), Barkaccha [lat. 25º10′, long. 82º45′]. The crop covers a total area of 300 ha, with a spacing pattern of 3.0 x 3.0 m amounting to 1111 plants per hectare in which 211 plants were dead on an average basis from each plant.

The area is characterized by seasonally dry tropical climate dominated by a typical monsoonal character. The year is divided into three seasons: winter (November–February), summer (March–mid-June) and rainy (late June–September). Mean monthly temperature ranges from 13.3–30.5 ºC and maximum from 23.2–40 ºC. The annual rainfall averages 1035 mm, of which 85% precipitates during rainy season from the south-west monsoon. The annual cycle experiences an extended dry period of about 9 months. The region is an erosional surface where the landscape is marked by plateau, summit, valley bottoms, ridges, isolated hills and sediments. The soils are residual, ultisol, sandy to sandy loam in texture and reddish brown in colour. The intensively leached soil is shallow, low in nutrients and organic matter and has moderate water holding capacity (WHC) (Singh *et al.* 1989).

Soil Sampling and analysis

Soil samples were collected periodically at three month interval (Jan and Apr.) from two depths i.e. 0-15 and 15-30 cm. To cover the heterogeneity in soils, the whole area was divided into nine plots; from each plot soil samples were collected in triplicate randomly from two depths. Each sample was thoroughly mixed; large pieces of the plant material were handpicked and sieved through a 2 mm mesh screen. In order to randomize, from each site, the soil samples were collected at a distance of at least 50 m. SOC was determined by the Walkley and Black method (Walkley 1947). Bulk density was determined by measuring the weight of dry soil of a unit volume.

Biomass estimation and carbon concentration

For estimation of carbon sequestered by the plant and the dynamics of soil organic carbon, the whole area was divided into nine plots. From each plot 15 plants were randomly selected for measurements of number of branches, height and basal diameter and crown width. Maximum and minimum heights as well as basal diameter among the 15 plants were recorded in January and April 2010 from different plots. To determine biomass, direct or destructive method (Watzlawick *et al.* 2002) was employed. For above and below ground biomass; fifteen plants were selected and excavated from each plot in January and April. Fresh samples were air dried for 2-3 days and then placed into oven at 75 ºC until the dry weight stabilized. The total plant biomass (leaves, branches and roots) was quantified by multiplying the average dry biomass of fifteen trees by the number of trees per hectare. For that, a density of 900 trees per hectare was considered. Litter fall estimation was done by collection of litter from 1 x 1 m^2 area every month during the study period.

For the determination of total carbon content in each tree component (shoot, roots, branches and leaves), composite samples were formed from the dry matter samples of this material. These samples were crushed in a cutting mill, gathering three 1g samples of each component. Each 1g sample was placed in a lidless porcelain crucible and taken to a muffle furnace set at 550°C for three hours, until calcinations was completed. The sample was then removed and cooled in calcinations to be later weighed. Carbon content was then calculated by the following equation:

CT=(Ms/Mr) x 100

Where: CT = Carbon content, in %; Ms = dry sample residue weight, after calcinations, in g;

Mr = dry sample weight, in g.

Conversion of carbon into CO_2 equivalent

As market trading of carbon credits is based on CO_2 equivalent (CO_2-e), converting carbon into CO_2 became mandatory. According to the Intergovernmental Panel on Climate Change – IPCC (2006), one ton of carbon equals 3.67 tons of CO_2-e, which is the ratio of molecular weight of CO_2 to carbon (44/12).

Results and Discussion

Litter fall

During the study period, Litterfall production showed no consistent trend with time as the mass of litterfall fluctuated ranging from 110 to 130 kg/ha. Maximum litter fall was recorded in April which was 15.38 % higher than the month of January. The average carbon content over the nine plots was 44.5%. Average carbon sequestered by litter fall was 51.6 kg C/ha whereas it was maximum in month of April (57.9 kg C/ha) and minimum in the month of February (47.2 kg C/ha) (Fig. 1).

Biomass production and carbon sequestered

Increased dry weight was observed in the aboveground component of the tree (excluding leaves) compared to below ground. Higher biomass production of *Jatropha curcas* from the aboveground portion of the tree compared to the belowground portion owed to the ability of the tree to adapt to drought without having to extend its root system to obtain water (Heller 1996, Ericsson *et al.* 1996). After third month (April) of measurements, the mean aboveground and belowground biomass was 1.96 and 0.44 t/ha respectively (Table 2). The percentage biomass accumulated by root alone in the month of January and April was 17.8 and 18.3 respectively. The mean carbon content in aboveground and belowground biomass were 48.7 and 44.7 (January) and 47.5 and 44.1 (April), respectively. Mean carbon sequestered by aboveground and belowground biomass for the month of April was 0.93 and 0.19 which was 8.6 and 10.5 % higher than the month of January (Table 1 and 2). The results indicate that *Jatropha curcas* stores substantial amounts of carbon (C) but this is predominantly stored in the aboveground portion of the tree compared to other parts.

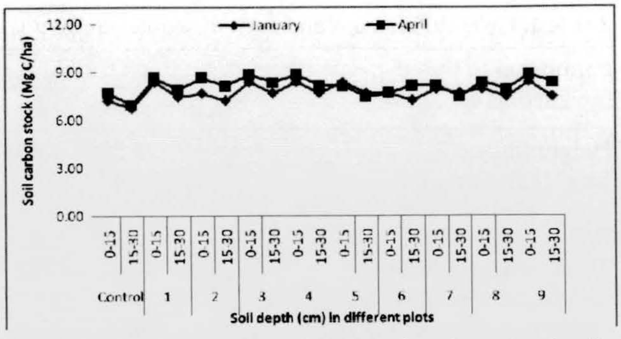

Fig. 2. Soil carbon stock under Jatropha plantation for the month of January and April in two soil depths

It would appear that using the 0.5 rule of thumb for estimating the carbon stock could easily lead to overestimation of Jatropha sequestration potential. The results that were presented in Table 1 and 2 also indicate a slight difference between the carbon fractions of the above-ground dry biomass and the below-ground dry biomass; this is again in line with the study by Firdaus *et al.* (2010), which also indicated slightly lower values for below-ground biomass. In calculating the carbon content of a tree, it is up to the researcher whether one fraction is used for the entire tree, or separate ones for the above- and below-ground parts. For considering Jatropha plantation in terms of carbon credits, total carbon sequestered should be represented in terms of CO_2 equivalent ($CO_{2\text{-}e}$). $CO_{2\text{-}e}$ for the month of January and April were 3.74 and 4.12 Mg $CO_{2\text{-}e}$/ha and percentage increase in $CO_{2\text{-}e}$ was 9.2, respectively (Table 1 and 2).

Soil organic carbon dynamics

Increasing carbon stocks in soil contribute to favourable soil conditions which in turn increase the resilience of the ecosystem against abiotic stresses.

Table 1. Growth, biomass and carbon sequestered by *Jatropha curcas* for the month of January, 2010

Parameters	Plot No.									Mean
	1	2	3	4	5	6	7	8	9	
Height (m)	1.23	1.16	1.50	1.60	1.80	1.85	1.75	1.95	1.55	1.60
Basel diameter (cm)	5.97	6.38	6.94	7.58	6.70	6.00	6.50	6.95	7.45	6.72
Above ground biomass (t/ha)	1.49	1.71	1.76	1.58	2.03	1.94	1.76	1.85	1.67	1.75
Below ground biomass (t/ha)	0.38	0.41	0.36	0.31	0.45	0.40	0.35	0.37	0.42	0.38
Total biomass (t/ha)	1.87	2.12	2.12	1.89	2.48	2.34	2.11	2.21	2.09	2.13
Carbon content in AGB (%)	48.6	48.7	49.6	47.9	48.5	48.7	49.3	47.8	49.0	48.7
Carbon content in BGB (%)	45.0	45.3	44.8	44.6	43.2	44.0	43.9	45.2	45.9	44.7
Carbon sequestered in AGB (Mg C/ha)	0.72	0.83	0.87	0.75	0.98	0.94	0.87	0.88	0.82	0.85
Carbon sequestered in BGB (Mg C/ha)	0.17	0.19	0.16	0.14	0.19	0.18	0.15	0.17	0.19	0.17
Total carbon sequestered (Mg C/ha)	0.89	1.02	1.03	0.89	1.17	1.12	1.02	1.05	1.01	1.02
CO_2 equivalent (Mg CO_{2-e} /ha)	3.27	3.74	3.78	3.27	4.29	4.11	3.74	3.85	3.71	3.74

Table 2. Growth, biomass and carbon sequestered by *Jatropha curcas* for the month of April, 2010

Parameters	Plot No.									Mean
	1	2	3	4	5	6	7	8	9	
Height (m)	0.99	1.25	1.95	1.75	2.03	1.82	1.82	2.16	1.75	1.72
Basel diameter (cm)	7.35	7.75	8.15	8.55	7.50	7.40	7.90	7.90	8.00	7.83
Above ground biomass (t/ha)	2.16	1.89	2.16	2.16	1.98	1.94	1.66	1.66	2.00	1.96
Below ground biomass (t/ha)	0.50	0.37	0.50	0.32	0.38	0.38	0.57	0.48	0.46	0.44
Total biomass (t/ha)	2.66	2.26	2.66	2.48	2.36	2.32	2.23	2.14	2.46	2.40
Carbon content in AGB (%)	49.3	47.5	48.3	46.7	45.5	48.3	47.2	46.8	47.5	47.5
Carbon content in BGB (%)	44.5	45.1	44.0	44.3	40.9	43.8	43.6	44.9	45.9	44.1
Carbon sequestered in AGB (Mg C/ha)	1.07	0.90	1.04	1.01	0.90	0.94	0.78	0.78	0.95	0.93
Carbon sequestered in BGB (Mg C/ha)	0.22	0.16	0.22	0.14	0.15	0.17	0.25	0.22	0.21	0.19
Total carbon sequestered (Mg C/ha)	1.29	1.06	1.26	1.15	1.05	1.11	1.03	1.00	1.16	1.12
CO_2 equivalent (Mg CO_{2-e} /ha)	4.73	3.89	4.62	4.22	3.85	4.07	3.78	3.67	4.26	4.12

Where, AGB= Aboveground biomass and BGB= Below ground biomass

Table 3. Dynamics of soil organic carbon in two soil depths after an interval of three months

Month	Soil depth (cm)	Plot No.										Mean
		Control	1	2	3	4	5	6	7	8	9	
January	0-15	0.31	0.36	0.33	0.36	0.36	0.36	0.33	0.34	0.34	0.36	0.35
	15-30	0.29	0.32	0.31	0.33	0.33	0.33	0.31	0.33	0.32	0.32	0.32
April	0-15	0.33	0.37	0.37	0.38	0.38	0.35	0.33	0.35	0.36	0.38	0.36
	15-30	0.30	0.34	0.35	0.36	0.35	0.32	0.35	0.32	0.34	0.36	0.34

Mean soil organic carbon percent for the soil depth (0-15 and 15-30 cm) in the month January were 0.35 and 0.32 while in month of April were 0.36 and 0.34 (Table 3). During the study period in Jatropha plantation it was observed that the soil organic carbon was slightly higher than control while decreased by the increase in soil depth. Mean soil carbon stock in upper (0-15 cm) and lower (15-30 cm) soil depth were 8.02 and 7.42 Mg C/ha (January) and 8.37 and 7.88 Mg C/ha (April) and gained percent increase of 4.18 and 5.8 in soil carbon stock, respectively (Fig. 2).

Conclusions

Although the study was of short duration for biomass production, carbon sequestration and soil carbon dynamics but still an effort was done to explore the variations in them, hence the prolong study can be advantageous for such research study. This research comprises all the necessary data for the estimation of

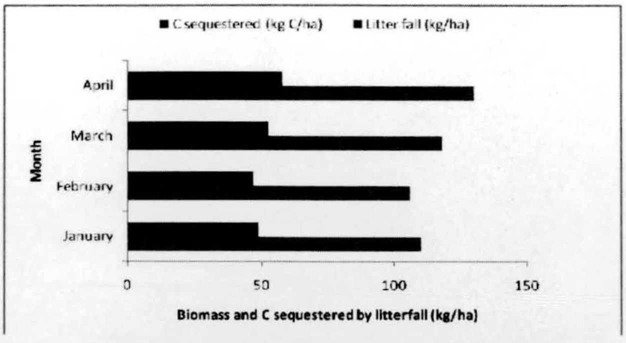

Fig. 1. Biomass and carbon sequestered by litter fall during the study period on monthly basis

carbon stocks for development of a carbon credit project with *Jatropha curcas*, and to estimate the contribution of carbon sequestration in Jatropha biomass in greenhouse gas life cycle analyses. The study confirms that the basal tree diameter is a very reliable predictor for the biomass in a tree, both aboveground and for the total tree. It would be used for the development of allometric equations to a range of environmental conditions. Therefore, we supposed that the equation developed for estimation of above-ground biomass can be more widely applied than the equation for the total biomass. There was 9 % increment in total carbon sequestered in Jatropha *curcas* within short period, which is good indication for its potential to reclaim degraded lands. This study aimed at developing knowledge at an indicative level and can be helpful to provide substantial estimations regarding the carbon sequestration potential of *Jatropha curcas* at Vindhyan Platue.

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