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Carbon sequestration potential in coconut-based cropping systems

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ABSTRACT

A field experiment was carried out in a coconut garden having red sandy loam soil at ICAR-CPCRI, Kasaragod, Kerala during May-July 2015 to study the effect of cropping system on above and below ground carbon sequestration in a 50-year-old plantation intercropped with seven-year-old fruit crops. Among the different cropping systems, coconut (*Cocos nucifera*) + *jamun* (*Syzygium cumini*) system sequestered the highest above ground carbon (60.93 t/ha) followed by coconut + mango (*Mangifera indica*) system with 56.45 C t/ha, coconut + garcinia (*Garcinia indica*) sequestered 53.02 C t/ha, whereas, coconut alone had sequestered 51.14 C t/ha. The below ground soil carbon stock in the rhizosphere of 0-60 cm depth was the highest in coconut + mango (82.47 t/ha) system followed by coconut + *jamun* (79.13 t/ha), coconut + garcinia (78.69 t/ha) and it was the lowest in coconut monocrop (47.06 C t/ha). The total carbon sequestration by coconut + *jamun* (140.06 t/ha) followed by coconut + mango systems (138.91 t/ha), coconut + garcinia (131.72 t/ha), whereas it was only 98.2 C t/ha under coconut monocrop.

Key words: Coconut, carbon stock, cropping system, plant biomass, soil organic carbon.

INTRODUCTION

Coconut (*Cocos nucifera* L.), the versatile palm with multifarious uses, is cultivated in the country predominantly by smallholders in tropical regions in 2.14 million ha with a production of 14911 (Anon, 2) million nuts and productivity of 7,000 nuts per hectare. Kerala, Tamil Nadu, Karnataka and Andhra Pradesh are the four major coconut producing states accounting for more than 90 per cent of the share in area and production. Monocropping of coconut is unsustainable as it utilizes only 45-50% of solar radiation, 21% of land area and the income derived from such a system is not sufficient to sustain even the small families (Maheswarappa *et al.*, 7). Further, coconut growers are frequently exposed to economic risks and uncertainties owing to rapid price fluctuations. Even through the current price situations are quite encouraging, coconut growers were badly affected for more than two decades due to low price/ price stagnation of coconut and escalating cost of cultivation. In this context, it is of paramount importance to promote coconut-based cropping systems as a strategy to enhance income. Coconut-based cropping systems, involving cultivation of compatible crops specially fruit crops in the interspaces will offer considerable scope for increasing production and productivity per unit area, time and input by more efficient utilization of resources like sunlight, soil, water and labour. In addition, it will be mimic a forest system and will have large scope for storage of carbon and removal of carbon dioxide from the atmosphere, thus playing a vital role in sustaining the environment. Many experiments have been conducted at ICAR-CPCRI, Kasaragod and still continuing with regard to studies on coconut-based cropping systems.

Carbon sequestration is a mechanism for removal of carbon from atmosphere by storing in the biosphere (Chavan and Rasal, 4). Soil carbon exchange with the atmosphere through soil respiration is also an important component of the global carbon cycle and it was estimated to be approximately 80 Pg C yr^{-1} (Raich and Potter, 12). It is now also well established that carbon pools in the soil have distinct residence times. The more recalcitrant material composing the majority of soil carbon is a low cycling carbon that it is not affected much by recent land use changes (Chen *et al.*, 5). It is possible for humans to manage soils in order to accumulate carbon or avoid high losses of it with cultivation (Lal, 7). The present investigation was carried out to quantify the above ground and below ground (soil) and total carbon storage in coconut-based fruit croppings.

MATERIALS AND METHODS

The present study was carried out at ICAR-CPCRI, Kasaragod, which is situated at 12°30' N latitude and 75°00' E longitude at an elevation of 10.7 m above mean sea level. The average annual rainfall received is 3,500 mm, of which 86 per cent is received during the four monsoon months (June-September). Observations were carried out in the ongoing experiment on coconut-based intercropping

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of fruit crops for sustainable production and nutritional security in Coastal Agro-Ecosystem during May to July 2015. The soil type is red sandy loam with pH of 5.5 to 6.0 and experimental design was RCBD. Crops in the cropping system were managed with the recommended package of practices. Fruit crops grown in the coconut garden are given below (Table 1).

Table 1. Fruit crop species grown as intercrop in coconut garden.

Common name	Scientific name	Age (yr)
Mango var. Amrapali	*Mangifera indica*	7
Kokam var. Konkan Amruta	*Garcinia indica*	7
Jamun var. Konkan Bahadoli	*Syzygium cumini*	7
Coconut var. WCT	*Cocos nucifera* L.	50

In the on-going experiment, above ground standing biomass and soil carbon stock were estimated by taking 10 trees and palms randomly in one acre plantation. For above ground standing biomass, non destructive method was adopted. In coconut, the girth was measured at 1.5 m height from the base and height was taken upto the base of the crown. The fruit crop trunk girth was measured at 1.3 m height from the base and total height of the species was recorded from the base of tree to top branch by using dendrometer. The diameter (d) was calculated by dividing π (3.14) to the actual marked girth of species (Bohre *et al.*, 3), and above Ground Biomass (AGB) was estimated by multiplying the bio-volume to the green wood density of tree species. Tree bio-volume (TBV) value established by multiplying square of diameter and height of tree species to factor 0.4.

Tree bio-volume = $0.4 \times (d)^2 \times h$
AGB = Wood density × TBV,
Where; d = Diameter (m),

Wood density was used from Global Wood Density database (Zanne *et al.*, 16).

Coconut biomass estimation was carried out by adopting standard procedure developed by Naresh *et al.* (9). Stem dry weight (kg) = Length (m)*girth^2 (in meter at 1.5 m above ground level)* 41.14142, Where length is the height of stem from ground level to base of the canopy and girth is the mean girth of stem at 1.5 m height from base. Carbon stock generally, for any plant species 50% of its biomass is considered as carbon (Pearson *et al.*, 10), *i.e.* Carbon stock = Biomass × 0.5 and for estimation of CO_2 (t/ha) sequestered by multiplying Carbon stock (t/ha) with 3.67 as factor.

For soil carbon stock estimation, soil samples were collected from the basin of the crops as per the standard procedures. Organic carbon content of soil was estimated by adopting Walky-Black's method and bulk density of the field was estimated by using core sampler at 0-30 and 31-60 cm depth described by Jackson (6). Soil carbon stock was estimated by following standard formula (Srinivasan *et al.*, 14). Soil organic carbon stock $_{(0\text{-}30,\ 30\text{-}60\ cm)}$ (Mg ha^{-1}) = [C concentration $_{layer}$ (kg Mg^{-1}) × (Bulk density) $_{layer}$(Mg m^{-3}) × Depth (m) × 10^{-3} Mg kg^{-1} × 10^4 (m^2 ha^{-1}).

Statistical analyses were performed using Statistical Analysis System 9.3 computer software (SAS Institute Inc., 13). DMRT procedure was used at P = 0.05 level to determine if there were significant differences between fruit crops under coconut garden at two depths for soil carbon stock estimation.

RESULTS AND DISCUSSION

As shown in Table 1, the average height and girth of mango was 7.8 and 0.58 m, respectively, *Kokam* was 6.08 m height with a girth of 0.36 m, *jamun* was 10.38 m height and had a girth of 0.64 m, whereas height of coconut was 20.72 m with a girth of 0.85 m. Among the fruit crops, *jamun* recorded the highest above ground biomass (130.19 kg/plant), which will be sequestering around 9.79 t/ha of C and 35.92 t/ha of CO_2. Estimated above ground biomass of mango was 70.76 kg/tree which will be sequestering around 5.31 C t/ha or 19.48 t/ha CO_2. In case of *G. garcinia*, biomass was 25.19 kg/plant with 1.89 C and 6.93 t/ha of CO_2 sequestration, whereas coconut had biomass of 574.7 kg/palm and sequestered 51.11 C t/ha or 35.92 t/ha of CO_2, which sequestered the highest CO_2 because of its higher biomass.

Among different cropping systems, the above ground standing biomass and above ground carbon stock recorded highest (121.85 and 60.93 t/ha, respectively) in coconut-based *jamun* cropping system followed by coconut + mango (112.88 and 56.44 t/ha) and coconut + garcinia (106.05 and 53.02 t/ha), whereas in coconut alone it was 102.27 and 51.14 t/ha, respectively (Fig. 1). In this study, coconut-based cropping system sequestered more carbon compared to coconut alone and this cropping system mimic like forest ecosystem. Trees are carbon reservoir on earth and in nature, forest ecosystem act as a reservoir of carbon. They store huge quantity of carbon and regulate the carbon cycle by exchange of CO_2 from the atmosphere. Thus, forest ecosystem plays important role in the global carbon cycle by sequestering a substantial amount of carbon dioxide from the atmosphere by storing it in the biosphere (Chavan and Rasal, 4).

The data presented in Table 2 represents soil organic carbon (%), bulk density (g/cm^3) and soil

Table 1. Crops and their growth parameters with above ground biomass and carbon stock under coconut garden.

Scientific name	Height (m)	Girth (m)	AGB (kg/plant)	C (kg/plant)	C (t/ha)	CO_2 (t/ha)
Mangifera indica	7.8	0.58	70.76	35.38	5.31	19.48
Garcinia indica	6.1	0.36	25.19	12.60	1.89	6.93
Syzygium cumini	10.4	0.64	130.51	65.25	9.79	35.92
Cocos nucifera	20.8	0.85	574.57	287.28	51.14	187.67

AGB = Above ground biomass, C = Carbon

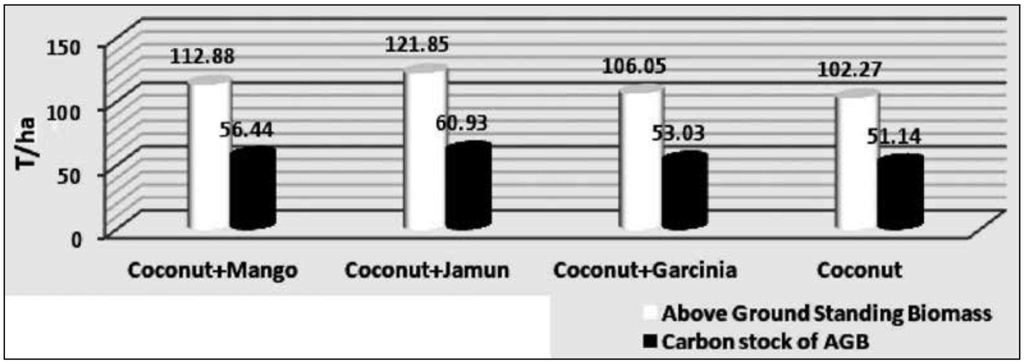

Fig. 1. Above ground standing biomass and carbon stock in coconut-based cropping systems.

carbon stock (t/ha) at 0-30 and 31-60 cm depth in the rhizosphere of different crops in the system. With respect to bulk density, there was no statistical significant difference among the different cropping system, and it was in the range of 1.58 to 1.64 g/ cm^3. Among the different fruit crops and coconut, the highest soil organic carbon (0.56 and 0.41%) was recorded in coconut basin at 0-30 and 31-60 cm depth, and it was followed by mango (0.43 and 0.31%), *jamun* (0.40 and 0.25%) and it was *on par* with garcinia (0.38 and 0.28%) and the lowest was recorded in interspaces (0.36 and 0.28%) where no crop is being grown. Among the different crops, coconut rhizosphere had sequestered more carbon (26.87 and 20.19 t/ha), followed by mango (20.52 and 14.89 t/ha), *jamun* (19.45 and 13.76 t/ha) and garcinia (18.31 and 12.18 t/ha) at 0-30 and 31-60 cm depth. The carbon sequestered in the interspace was the lowest (17.09 and 13.87 t/ha) at 0-30 and 31-60 cm depth, respectively might be due to absence of crops and management practices. Coconut basin rhizosphere had recorded high carbon stock at both depths (0-30 and 31-60 cm), which might be due to increase in organic carbon in the soil due to decomposition of root system over a period of time and organic manure incorporation to the coconut crop as compared to other crops and interaction effect of organic manure and green manure incorporation by sustainable practice. Similar findings were observed in orchard, the beneficial effects of sustainable practices (Residue incorporation, cover crop retention and compost application) on yield which was improved by 30-50% as compared with conventional managed orchards (Xiloyannis *et al.*, 16; Poirier *et al.*, 11).

Table 2. Estimated soil carbon stock of coconut and different fruit crops.

Treatment	Organic carbon (%)		Bulk density (gcm^{-3})		Soil carbon stock (t/ha)	
	0-30 cm	31-60 cm	0-30 cm	31-60 cm	0-30 cm	31-60 cm
Coconut- *Cocos nucifera*	0.56^{a}	0.41^{a}	1.59	1.63	26.87^{a}	20.19^{a}
Mango-*Mangifera indica*	0.43^{b}	0.31^{b}	1.58	1.61	20.52^{b}	14.89^{b}
Garcinia-*Garcinia indica*	0.38^{cd}	0.28^{bc}	1.61	1.63	18.31^{cd}	12.18^{c}
Jamun -Syzygium cumini	0.40^{c}	0.25^{c}	1.63	1.64	19.45^{bc}	13.76^{bc}
Interspace	0.36^{d}	0.28^{bc}	1.60	1.62	17.09^{d}	13.87^{bc}
CD at 5%	0.03	0.04	NS	NS	1.37	4.11

Among the coconut-based cropping system, the carbon stock was the highest in coconut + mango system (47.39 and 35.08 t/ha) followed by coconut + *jamun* (45.18 and 33.95 t/ha) at 0-30 and 31-60 cm depth, respectively compared to other cropping systems (Fig. 2). The actual amount of soil carbon that can be stored is dependent on the farming system (management practices), soil type and climatic conditions and initial soil carbon level of the site (Anon, 1).

The total carbon stock involving above and below ground is depicted in the Fig. 3. Total carbon stock recorded in the coconut + *jamun* system was the highest (140.06 t/ha) followed by coconut + mango (138.91 t/ha) and coconut + garcinia (131.72 t/ha) system, whereas, coconut monocrop recorded lower total C stock (98.2 t/ha). Higher C storage in the intercropping system was due to additional storage of carbon by these fruit intercrops. As depicted in Fig. 4, CO_2 sequestration recorded followed the same trend and it was the highest in coconut + *jamun* (514.00 t/ha) system followed by coconut + mango (509.80 t/ha), coconut + garcinia (483.39 t/ha) and the lowest

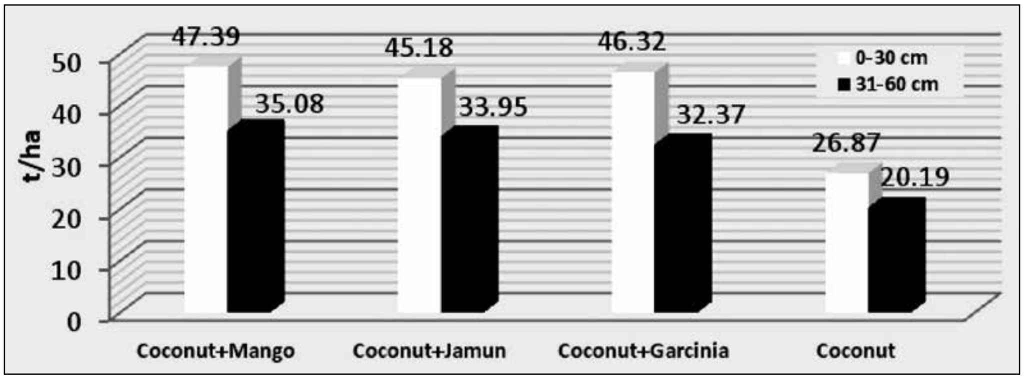

Fig. 2. Soil carbon stock in coconut-based fruit cropping systems.

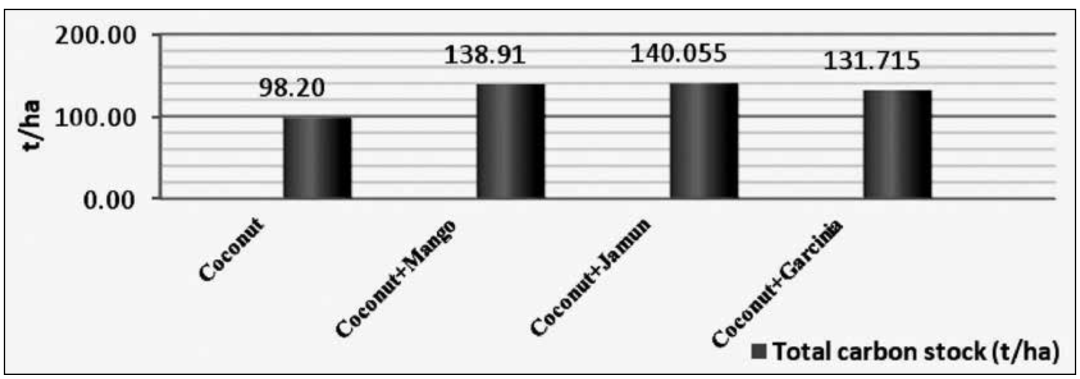

Fig. 3. Total carbon stock in coconut-based fruit cropping systems.

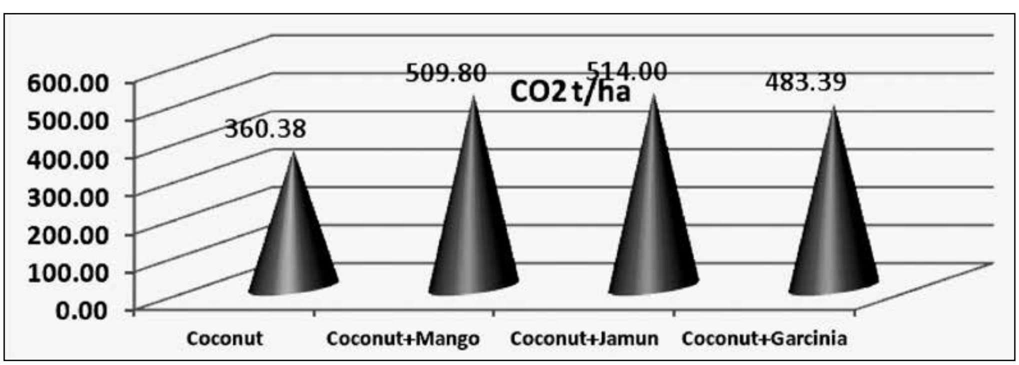

Fig. 4. Amount of CO_2 sequestered by coconut-based fruit cropping systems.

(360.38 t/ha) was recorded in coconut mono-cropping system. This result is due to higher carbon storage by growing intercrops especially perennial crops as compared to mono-cropping system. Thus, by cultivating intercrops in the interspace of coconut, storage of carbon in the soil and above ground can be expected. By intercropping with fruit crops like *jamun*, mango and *kokam*, can get additional income and benefit of carbon storage, removal of CO_2 from the atmosphere as compared to the monocropping of coconut. Further study is required to recommend fruit crops suitable for intercrop in coconut and ecologically feasible in different locations.

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