# CARBON SEQUESTRATION POTENTIAL IN COCOA PLANTATIONS

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## Introduction

Capturing of atmospheric carbon (C) and storing it in the terrestrial biosphere is one of the options, which have been proposed as a mitigation option for greenhouse gas (GHG) reduction. Forests, cultivated lands and grass lands are sources of carbon sequestration apart from soil. In United Nations Framework Convention on Climate Change (UNFCCC) clean development mechanism, agroforestry (Albrecht and Kandji, 2003; Montagnini and Nair, 2004), forestration and reforestration (Shrestha *et al.,* 2005) are designated for carbon trade. Thus, agroforestry as a land-use system is receiving wider recognition not only in terms of agricultural sustainability but also in the perspective of climate change. Efforts are on to include some other perennial systems like plantation crops into this mechanism. Once these systems are approved for carbon trade, one can expect large demand for plantation crop systems in terms of information on carbon sequestration potential and sustainable productivity. The areca-cocoa mixed crop not only gives a sustainable production, but also serves as a good system for biomass production and carbon accumulation. Agroforestry systems of cocoa with shade trees have been reported to be good examples of biomass production in Costa Rica (Beer *et al.,* 1990).

Arecanut is grown either as mono-plantation or intercropped with other plantations like cocoa, banana, etc., whereas, cocoa is grown only as an intercrop of either coconut or arecanut. The area under arecanut is about 0.374 million hectares, which provides shade for under-storied cocoa, forming considerable amount of land use system that provides sustenance to over six million people. Demand for cocoa is ever increasing in India and also at global level, making this plantation crop more remunerative. On the other hand, arecanut is being consumed at local and national level. However, the income levels of farmers are highly fluctuating owing to market dynamics. These suggest the importance of stable income from arecanut-cocoa plantation systems. Exploiting carbon sequestration potential of this system is important not only for augmented income but also for mitigating GHG emissions in the perspective of climate change.

With this in view, a project on carbon sequestration was started in areca and cocoa mixed cropping system to evaluate the net primary productivity and carbon sequestration potential. In this paper, use of models to calculate biomass, the net primary productivity in terms of biomass production and carbon sequestration in the system are discussed. The objective of this paper was to analyze carbon sequestration and storage in areca-cocoa tropical agro forestry systems and to discuss the role they can play in reducing the concentration of $CO_2$ in the atmosphere.

## Materials and Methods

Cocoa is grown within 20ºN and 20ºS latitude, upto 500 m altitude. On the other hand, arecanut is grown in 28ºN and 28ºS latitude and 1000 m altitude. Data were collected from areca-cocoa mixed crop experiments laid out in Research Farm, CPCRI, Regional Station, Vittal (75ºE longitude, 12ºN latitude, 90m altitude) during 1991. Soil is lateritic in nature with 5.4 pH. Cocoa plants were spaced at 2.7 x 5.4 m within areca plantation spaced at 2.7 x 2.7 m. Plants were given fertilizers *viz.,* NPK @ 100:40:140 and irrigated regularly (20L/day) during dry season from December to June. All other management practices were followed as per recommended management package.

The regression model developed for areca is given below:

Total dry weight = 6.0719 - 3.9038 H + 0.9222 $H^2$

Where, H is the height of palm (m) upto the base of the crown.

Using this regression model, it is possible to estimate dry biomass of areca by giving palm height (below crown) as an input. The $R^2$ for this model is 0.93 indicating high efficiency for estimating biomass.

In case of cocoa, model developed earlier for biomass estimation was used (Balasimha and Nair, 1989). The regression model for cocoa is as follows:

Total dry weight = - 8.41 + 0.47 CA + 0.28 SG + 2.69 SH

Where CA - canopy area ($m^2$), SG - stem girth (cm) and SH - stem height (m) upto base of crown.

**Biomass estimations in cocoa-areca systems**

Measurements on growth parameters *viz.,* stem height, girth, canopy spread, canopy height on cocoa, and stem height and girth of areca plants in 300 $m^2$ area were taken for estimating the biomass using regression equations. Data were taken on 21 cocoa and 36 areca plants for calculating the biomass during each year. Results are up-scaled to hectare basis with 1350 areca palms and 675 cocoa trees. All parts of plant like pruned biomass, ripe nuts and pods were accounted for total biomass estimations. Data on pod and bean yield (in case of cocoa) and nut yield (in case of arecanut) were collected from the experimental plot. All data collected as mentioned above were summed to get total above ground biomass production.

Carbon in different plant part samples like tissues of stem, leaf, twigs, pods, husk, nuts and beans was estimated by combustion method (Kalra and Maynard, 1991) modified for plant samples. Accurately weighed oven dried plant samples were combusted in a muffle furnace at 500$^{o}$C for 6 hrs. Combusted portion formed the carbon percentage of tissue. Results indicated that the percentage of carbon in different tissue was about 40 to 44%. Annual increments in biomass and carbon content were also computed. From these basic data the carbon sequestered was calculated. Carbon content in standing biomass formed carbon stock. From the experimental plot soil samples were collected at 30, 60 and 90 cm depth from the basins of arecanut and cocoa plants. Soil organic carbon was estimated following the modified method of Walkley and Black (1934) as described in (Kalra and Maynard, 1991).

**Results and Discussion**

**Standing biomass, Carbon stocks, Net primary productivity and Carbon sequestration**

The results indicate that arecanut standing biomass increased from about 5 t $ha^{-1}$ in third year of field planting to about 85 t $ha^{-1}$ by the time plantation attained 15 years age after field planting (Fig. 1). This accounts to an annualized increment in biomass of about 5.6 t $ha^{-1}$. However, this can vary significantly depending on the nut yield which ranged from 0.837 to 1.790 kg $plant^{-1}$ during 15 years period with a dry weight varying from 1.129 to 2.416 t $ha^{-1}$. Arecanut yield stabilizes after eight years of field planting (Balasimha, 2001).

The areca and cocoa plant samples were estimated for total carbon contents. The carbon content in areca and cocoa plant parts ranged from 39-42 per cent. The concentration of carbon in tissue is multiplied with biomass to get the carbon stocks in arecanut plants. Such standing carbon stocks varied from 2 t $ha^{-1}$ in the third year after field planting to 35 t $ha^{-1}$ by $15^{th}$ year after field planting. This makes an annualized increment of carbon stock to about 2.3 t $ha^{-1}$. Similarly, model developed for cocoa (Balasimha and Nair, 1989) was used to estimate the biomass production by cocoa plants. Estimated cocoa standing biomass accumulated from about 3 t $ha^{-1}$ in third year of field planting to about 27 t $ha^{-1}$ by the time plantation attained 15 years age after field planting (Fig. 2). This accounts to an annualized increment in biomass of about 1.8 t $ha^{-1}$. As in case of arecanut, this can vary significantly depending on the pod yield which ranged from 0.473 to 1.237 kg $plant^{-1}$ during 15 years period with a dry weight varying from 0.319 to 0.834 t $ha^{-1}$.

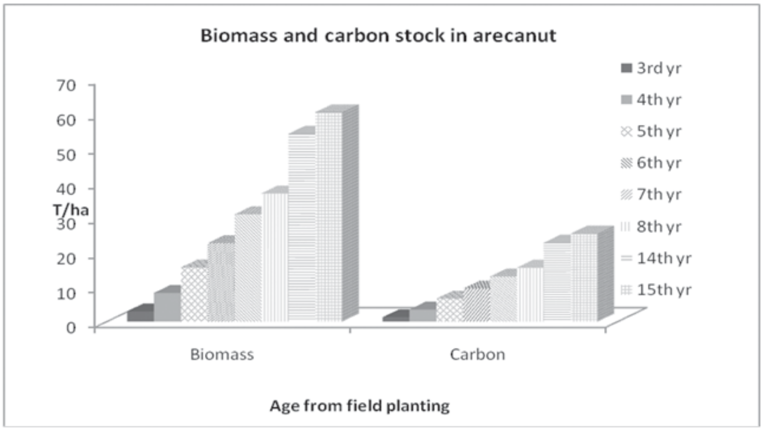


**Fig.1. Biomass and carbon stock in arecanut**

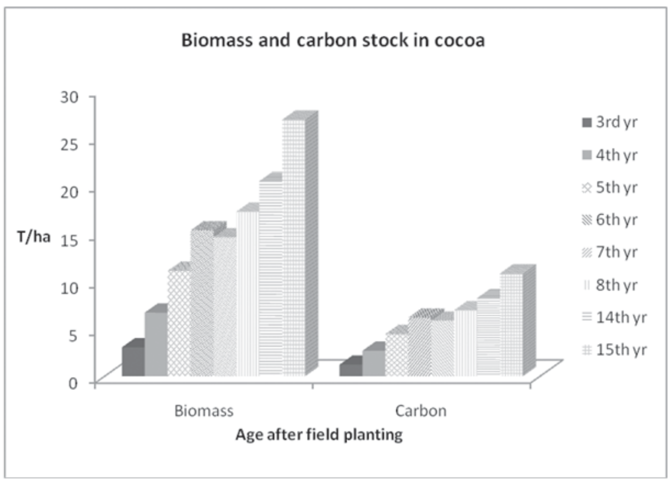


**Fig.2. Biomass and carbon stock in cocoa**

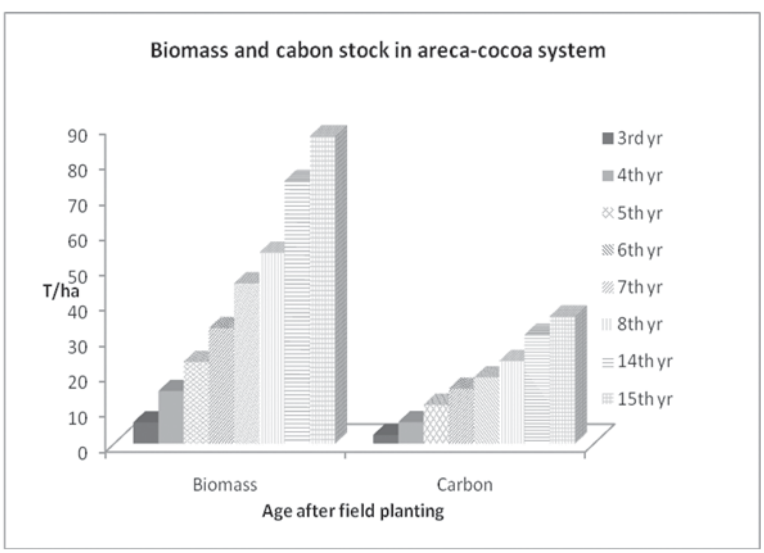


**Fig.3. Total biomass and carbon stock**

The concentration of carbon in tissue is multiplied with biomass to get the carbon stocks in cocoa plants. Such standing carbon stocks varied from 1.5 t $ha^{-1}$ in the third year after field planting to 10 t $ha^{-1}$ by $15^{th}$ year after field planting. This makes an annualized increment of carbon stock to about 0.6 t $ha^{-1}$. In arecanut-cocoa plantations, the total biomass production is obtained by summing up the biomass of arecanut and cocoa plants in proportion of their population in one hectare. Thus, total standing biomass of areca-cocoa plantations was 26.57, 54.09 and 87.10 t $ha^{-1}$ in $5^{th}$, $8^{th}$ and $15^{th}$ years after field planting, respectively (Fig.3). Contribution of arecanut plants towards biomass accumulation was greater as compared to that of cocoa.

Estimates of annual biomass increments ranged from 1.38-2.66 t $ha^{-1}$ in cocoa and 3.34-7.11 t $ha^{-1}$ in areca. This represents the net primary productivity in the mixed crop system over the 15 years period (Table 1). These variables showed higher values during later years as compared to early years of growth indicating greater partitioning of biomass towards economic yield in later years of study. The annual standing carbon contents of cocoa and areca showed increasing trend parallel to biomass values (Fig. 2 & 3). Similarly, the total of both crops is also presented in Fig.3. Annual $CO_2$ sequestration ranged from 2.02-3.89 and 5.14-10.94 in cocoa and areca, respectively (Table 1).

**Table 1. Annual net primary productivity, carbon stock increments and $CO_2$ sequestration in areca-cocoa system**

| Parameter | Annual increment (t $ha^{-1}$) in areca | | | Annual increment (t $ha^{-1}$) in cocoa | | |
|---|---|---|---|---|---|---|
| | 3-5 years | 6-8 years | 9-15 years | 3-5 years | 6-8 years | 9-15 years |
| Biomass | 4.21 | 7.11 | 3.34 | 2.66 | 2.06 | 1.38 |
| Carbon stock | 1.78 | 2.98 | 1.40 | 1.06 | 0.83 | 0.55 |
| Net $CO_2$ sequestration* | 6.53 | 10.94 | 5.14 | 3.89 | 3.05 | 2.02 |

*1 $CO_2$ t.$ha^{-1}$ = C (t.$ha^{-1}$) x 3.67

Mitigation of green house gas emission is one of the important aspects related to quest against climate change. Carbon sequestration by terrestrial biomass is one of the mitigation options used for reduction of GHGs. Agroforestry systems provide opportunity for carbon sequestration under clean development mechanism (CDM). Arecanut cocoa based agroforestry systems produce abundant biomass to qualify for this. The standing biomass increased over time indicating accumulation of biomass in stem and also due to increase in yield by arecanut and cocoa plant with age upto $15^{th}$ year of planting. Arecanut produces stable yield from eight years after planting (Balasimha, 2001). In case of cocoa yield stabilization takes place around five years of field planting (Balasimha, 2001). Around 30-50% of photosynthetically active radiation is transmitted through arecanut canopy (Balasimha, 1989; Balasimha and Subramonian, 1984). Cocoa, with its compact and high leaf area, is able to intercept 90% of the remaining PAR. Cocoa production under shade trees has been reported to be 1t $ha^{-1}$ $year^{-1}$ in Costa Rica (Beer *et al.*, 1990). However, biomass production under arecanut and cocoa agro forestry system under tropical conditions prevailing in India is higher. The microclimate especially shade, soil moisture and temperature in arecanut gardens were found to be ideal for cocoa growth and productivity (Shama Bhat and Bavappa, 1972). Moreover these systems are reported to be highly compatible at arecanut and cocoa population ratio at 1:2.

Carbon estimations, done on the basis of biomass and carbon percentage in tissue indicate net carbon sequestration by arecanut-cocoa system. However, these include the uncertainties related to future shifts in global climate, land-use and land cover, the poor performance of trees and crops on substandard soils and dry environments, pests and diseases. In addition, more efforts are needed to improve methods for estimating carbon stocks and trace gas balances such as nitrous oxide ($N_2O$) and methane ($CH_4$) to determine net benefits of agro forestry in the atmosphere.

The study has thus revealed that the biomass and primary productivity is considerable with areca-cocoa mixed crop and comparable to any agroforestry systems involving cocoa (Alpizar *et al.,* 1986; Beer *et al.,* 1990). However, in view of the fact that only afforestation and reforestration systems can be used for CDMs (Shrestha *et al.,* 2005), the areca-cocoa system cannot be considered for carbon trade under clean development mechanism as of now. However, these methods on above ground biomass and carbon estimations provide useful basic information on these aspects and can be used as models in future, if there is any change in the policies before or after 2012 when International Panel on Climate Change (IPCC) is to renegotiate the procedures.

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