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Quantitative Estimation of Carbon Stock and Sequestration in Cashew Nut (Anacardium Occidentale) and Mango (Mangifera Indica) Orchards in Gujarat's Valsad District

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ABSTRACT

To determine the carbon stock and sequestration of mango and cashew nut orchards in Kaprada and Dharmapur tehsils of Valsad District, Gujarat. The field survey was conducted on the family's farm of 60 mango and cashew nut orchards of ages between 11 to 20 years. The age categories are further separated into two subgroups: those aged 11 to 15 and 16 to 20 years. The carbon sequestration potential of trees in the orchard was estimated using the non-destructive harvesting method in the sample size of 15 x 15 m quadrate sampling method in each plot.

The volumetric equation was used to determine the potential carbon stored in the woody biomass of mango trees and the 11 to 15 age group estimated that, the carbon stock 16.1 MT or 58.9 MT CO_{2e} from woody biomass produced in 6 ha. Similarly, in the Cashew orchard of 11 to 15 age group, it is estimated the carbon stock was 11.4 MT or 41.9 MT CO_{2e}.

In the age group of 16 to 20 years of Mango orchard, the potential carbon store was 34.2 MT, or 125.5 MT CO_{2e}, and in cashew nut orchards the carbon stock in woody biomass was 30.2 MT, or 110.6 MT CO_2e from 6 ha area. The study revealed that mango and cashew nut orchards store significant soil carbon. In the 11–15 year age group, mango orchards stored 20.8 MTha $^{-1}$ (76.1 MTha $^{-1}$ CO_2e) and cashew nut orchards 19.1 MTha $^{-1}$ (69.9 MTha $^{-1}$ CO_2e). In the 16–20 year age group, mango orchards stored 42.8 MTha $^{-1}$ (156.9 MTha $^{-1}$ CO_2e) and cashew nut orchards 23.5 MTha $^{-1}$ (86.1 MTha $^{-1}$ CO_2e). The results highlight the increasing carbon sequestration potential with orchard age.

Key words: *Soil carbon, Orchards, Carbon stock, and Sequestration*

INTRODUCTION:

Agriculture, fruits, vegetables, fisheries, and trees are among the food systems that are predicted to be significantly impacted by climate change. One of the most important problems the world is now dealing with is global warming. Earth's average temperature rises due to an increase in greenhouse gases, particularly carbon dioxide, in the atmosphere. Deforestation and the use of fossil fuels are the primary causes of the increase in CO_2 emissions (Pragasan 2014). The primary goal of the Conference of the Parties (COP's) of the United Nations Framework Convention on Climate Change (UNFCCC) is to reduce carbon dioxide emissions, as it is the primary greenhouse gas directly responsible for raising the average world temperature. The second-largest emitting sector in the world, agriculture, forestry, and other land-use systems (AFOLU), accounts for 23% of yearly greenhouse gas emissions from an area of around 22 million km^2 (Lynch et al., 2019; IPCC 2021). It will probably rise since the world will need to feed 10 billion people by 2050, necessitating a more intensive agricultural production system that uses more chemicals, high-yielding breeds and varieties, and machinery. The environment is being disturbed by rising GHG concentrations in the atmosphere, leading to severe global warming and its related effects (Pathak et al., 2021; Pathak 2022). The Inter-Governmental Panel on Climate Change (IPCC) recently released its Sixth Assessment Report (2021), which emphasized the need for immediate action to reduce the continuously rising emissions. GHG emissions in the atmosphere are increasing at a rate of 2.4 parts per million annually, and the concentration of atmospheric CO_2 has risen from 278 parts per million in the pre-industrial era (1970) to 415 parts per million in 2021 (IPCC 2021).

Objectives of this study:

This study's primary goal is to calculate the total carbon stock content of the biomass found above and below ground in cashew nut and mango orchards. To examine the soil's carbon store beneath cashew nut and mango trees and the potential for carbon sequestration in a few chosen orchards at various age groups.

MATERIAL AND METHODS:

Keshar, a grafted mango variety, was planted 10 x 10 meters apart, and Vengurla-4, a grafted cashewnut variety, was planted 7 x 7 meters apart. The trees on these orchards were between 10 and 15 years old and 16 and 20 years old at the time of the study. Thirty mango orchards and an equal number of cashewnut orchards were chosen for the study from the Kaprada and Dharmpur cluster (Dist. Valsad) at each location.

Field sampling units (Quadrat method):

The amount of carbon sequestered by cashewnuts and mangoes, as well as the amount of biomass generated both above and below ground, must be known. NON-DESTRUCTIVE sampling techniques were used to carry out the entire investigation.

(Mac Dicken 1997, Kuhns, Michael 1997, Bohre et al. (2013)

Measurements

We'll measure the height and diameter at the breast height (DBH) of selected trees in each orchard. The estimate of the biomass of cashew nut and mango trees both above and below ground was done using non-destructive methods. Measurements of the trunk and crown of individual trees were used to estimate biomass using established allometric relationships. We'll use the formula developed by MacDicken (1997) to determine the biomass of roots below ground. By analyzing the soil at the top 30 cm layer, the amount of organic carbon in the soil was estimated.

Tree height

Tree height will be measured using the method described by Kuhns, 1997 or the direct tree height of small trees will be measured using measuring tape. The method involved walking toward or away from the tree while holding a stick vertically until the tip of the stick is visually lined up with the top of the tree and bottom of the stick is lined up with the bottom of the tree. At this point, the distance from the eye to the base of the tree is equal to the height of the tree.

Procedure:

a. Take a stick that is equal in length to the distance from the eye (Check bone) when the arm is fully extended in front of the face.

b. Grasp the stick by the tip of the thumb and index finger and hold it in front with the arm fully extended. The stick must be held vertically.

c. Walk toward or away from the tree until the tip of the stick is visually lined up with the top of the tree and the bottom of the stick is lined up with the bottom of the tree.

d. The distance from the eye to the base of the tree is equal to the height of the tree.

1. Tree circumference

By measuring the girth at DBH and the diameter at breast height (DBH) directly, mathematical models can calculate the biomass. A tree's diameter more than 10 cm will be regarded as a tree and measured, and the girth is determined by measuring the DBH at breast height, which is approximately 1.3 meters.

2. Volume over the bark

As no equation is available to indirectly estimate the volume over the bark (VOB), the following equation derived by Bohre et al., 2013 for Gmelina arborea, based on maximum correlation coefficient and minimum standard error, was used for mango and cashew nut, VOB = - $0.017+0.003D+0.0014H+1.899 \times 10^{-5} D^2H$. Where VOB = volume over the bark in cm; D = diameter at breast height in cm and H = height of the tree in meters.

3. Tree biomass

The wood biomass in kilogram will be calculated by multiplying the volume with the wood density of Mango (0.55 g cm^{-3}) and Cashewnut (0.42 g cm^{-3}). Based on individual wood density the tree biomass was calculated based on the below equation, (FAO 1997)

AGB = V x WD x BEF x 1000 where AGB = Above Ground Biomass; V = Volume of the tree; WD = Wood density; BEF = stem wood biomass expansion factor (BEF =1.5) which includes leaves, twigs, branch, and bark.

(Zanne et al., 2009 and Pandey, 2012)

The belowground biomass was estimated as 20% of the aboveground biomass as reported by Santantonio et al., 1997 and Mac Dicken, 1997.

BGB = AGB x 0.2.

The total standing tree biomass was calculated as Total biomass =AGB + BGB.

4. Soil samplings from Mango and Cashewnut fruit orchards:

To determine the soil's bulk density (BD) and amount of soil organic carbon, soil samples were taken from each orchard. After that, the total carbon stock in the soil was estimated.

5. Soil organic carbon, carbon stock and carbon sequestration rate:

The equation derived by Yeoman will be used to calculate soil organic carbon (SOC) as follows: SOC ha^{-1} = Total volume of soil ha^{-1} x % SOC / 100 where volume of soil is 3048 metric tons at a soil density of 1.2. Carbon stock (C) was calculated by multiplying the total biomass by the widely used coefficient of 0.55 as described by Mac Dicken, 1997. C = 0.55 x total biomass. Carbon dioxide sequestered by different tree species will be calculated by multiplying total calculated carbon stock in tree woody biomass by atomic weight of the carbon 3.6663 (USDE, 1998).

Sequestration of CO_2 or Equivalent CO_2 = Carbon stock x 3.6663.

Location of Mango and Cashew nut orchards:

The study was conducted in the Kaprada cluster (20.3442° N, 73.2183° E) in the Valsad district of Gujarat state. The average annual rainfall of Kaprada is 2325 mm, and a maximum of 49 °C and minimum temperature 12°C were recorded. (https://www.accuweather.com/en/in/valsad/188155/current-weather/188155). The orchards developed by BAIF belonging to economically disadvantaged farmers were selected for the study. During the survey, the latitude and longitude were recorded from each orchard. The survey was completed from Nandgam, Chandvengana, and Kaprada villages of Kaprada block and Dandval, Piramal, and Nani Kosbadi villages from Dharmapur block of Valsad District Gujrat. The survey of 15 Mango and 15 Cashewnut orchards having an age group of 10 to 15 years and for same orchards having an age group of 16 to 20 years was completed.

RESEARCH DISCUSSION:

The age-wise above and below-ground biomass, total biomass, volume, Carbon stock, and sequestration potential in Mango orchards

For the mango orchards, in both age groups, 6 hectares of land were covered during the survey with recording the physical observations like tree height, Diameter at Breast Height (DBH), above and below ground biomass, carbon stock, and sequestration potential.

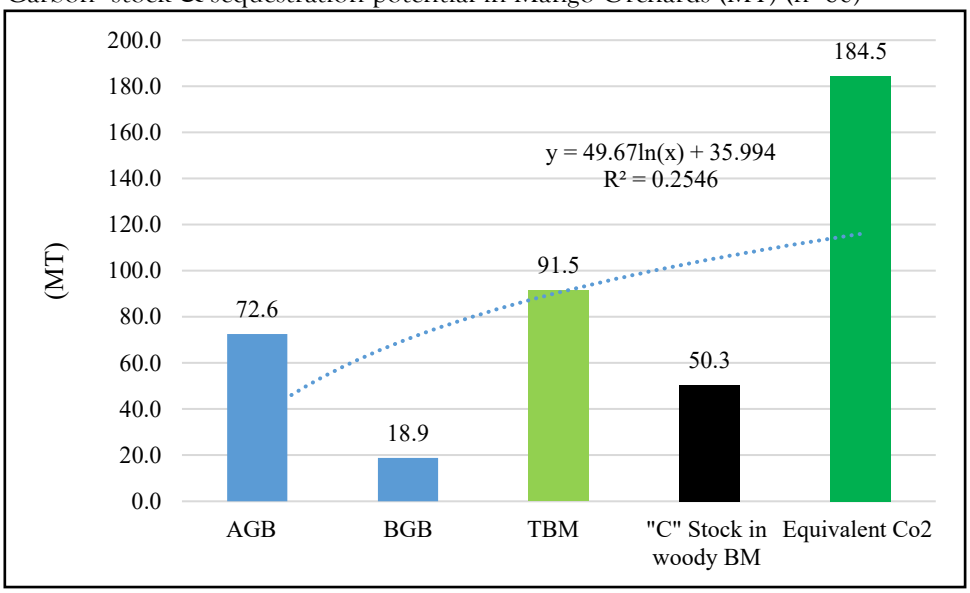
Table 1: Carbon stock in different age groups in Mango orchards (MT) (n=60)

Age group of Orchards	Samples trees	No. of trees in orchards	Area in ha	Volume (m^3)	AGB (MT)	BGB (MT)	TBM (MT)	"C" Stock in BM (MT)	Equivalent CO_2 (MT)
11 to 15 years	60	317	3	28.1	23.2	6.0	29.2	16.1	58.9
16 to 20 years	60	335	3	59.9	49.4	12.8	62.3	34.2	125.5
Total	120	652	6	88.0	72.6	18.9	91.5	50.3	184.5
Per ha									
11 to 15 years	20	106	1	9.4	7.7	2.0	9.7	5.4	19.6
16 to 20 years	20	112	1	20.0	16.5	4.3	20.8	11.4	41.8

A total of 60 Mango sample tree were randomly selected during the survey from 6 ha of land. It was recorded that the age group of 11 to 15 years old Mango orchards Above Ground Biomass (AGB) was 23.2 MT, Below Ground Biomass (BGB) was 6.0 MT and total biomass was 29.2 MT. The C stock in woody biomass is 16.1 MT and has the potential to sequester 58.9 MT Co_2e from 60 sample trees. Similarly, the age group of 16 to 20 years old Mango orchard's Above Ground Biomass (AGB) was 49.4 MT and Below Ground Biomass (BGB) was 12.8 MT and total biomass is 62.3 MT. The C stock in woody biomass was 34.2 MT and has the potential to sequester 125.5 MT Co_2e from 60 sample trees. In Mango orchards carbon stock in woody biomass at the age between 11 to 15 years old trees was 5.4 $MTha^{-1}$, which

was equivalent to 19.6 MTha^{-1} CO_{2e}. Similarly at the age group between 16 to 20 years tree carbon stock in woody biomass is 11.4 MTha^{-1} and is equivalent to 41.8 MTha^{-1} CO_{2e} (Table-1). Carbon sequestration potential of mango was assessed by Selvaraj et al. (2016) in the southern agro-climatic zone of Tamil Nadu. The reported total standing biomass of mango was 1.85 to 80.74 MTha^{-1} in mango of 5-20 years of age. The study conducted by Nimbalkar et.al 2017 reported that the biomass accumulated by mango trees of an average age of 10 years was 4.5 MTha^{-1} which was equivalent to 18.8 MTha^{-1} of CO_2.

Graph 1: "Carbon" stock & sequestration potential in Mango Orchards (MT) (n=60)



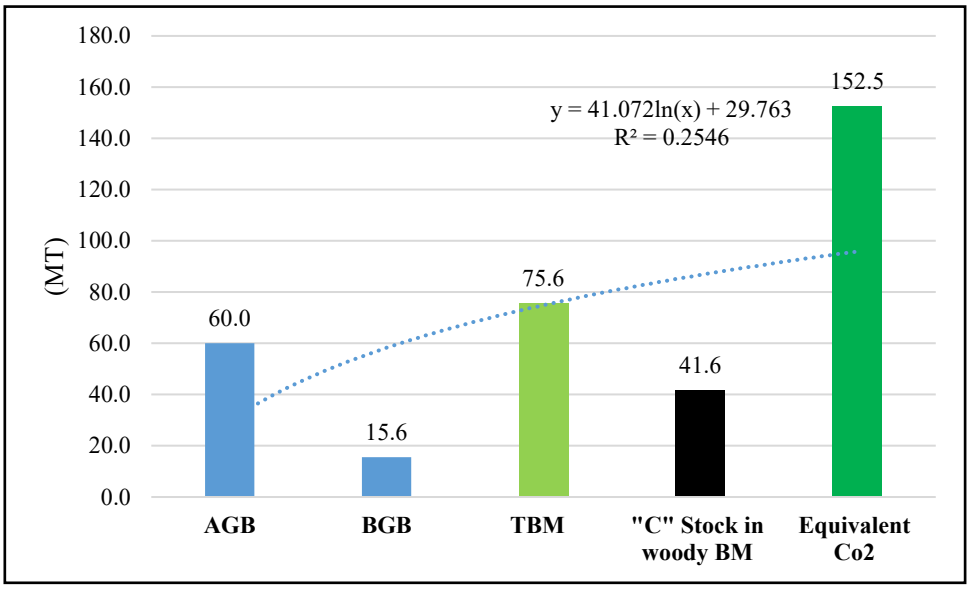
The age wise above and below ground biomass, total biomass, volume, Carbon stock and sequestration potential in Cashewnut orchards

A total of 60 Cashewnut sample tree observations were taken during the survey from 6 ha of land. It was recorded that the age group of 11 to 15 years old Cashewnut orchards Above Ground Biomass (AGB) was 16.5 MT, Below Ground Biomass (BGB) was 4.3 MT and total biomass was 20.8 MT. The C stock in woody biomass is 11.4 MT and has the potential to sequester 41.9 MT Co_2e from 60 sample trees. Similarly, in the age group of 16 to 20 years old Cashewnut orchard's Above Ground Biomass (AGB) was 43.5 MT and Below Ground Biomass (BGB) was 11.3 MT and total biomass is 54.9 MT. The C stock in woody biomass was 30.2 MT and has the potential to sequester 110.6 MT Co_2e from 60 sample trees. In Cashewnut orchards carbon stock in woody biomass at the age between 11 to 15 years old trees was 3.81 MTha^{-1}, which was equivalent to 13.98 MTha^{-1} CO_{2e}. Similarly at the age group between 16 to 20 years tree carbon stock in woody biomass is 10.0 MTha^{-1} and is 36.8 MTha^{-1} CO_{2e} (Table-2).

Table 2: Carbon stock in different age group in Cashewnut orchards (MT) (n=60)

Age group of Orchards	Samples trees	No. of trees in orchards	Area in ha	Volume (m^3)	AGB (MT)	BGB (MT)	TBM (MT)	"C" Stock in BM (MT)	Equivalent CO_2 (MT)
11 to 15 years	60	190	3	26.2	16.5	4.3	20.8	11.4	41.9
16 to 20 years	60	384	3	66.5	43.5	11.3	54.9	30.2	110.6
Total	120	574	6	92.7	60.0	15.6	75.6	41.6	152.5
Per ha									
11 to 15 years	20	63.3	1	8.7	5.5	1.43	6.9	3.8	13.9
16 to 20 years	20	128.0	1	22.1	14.5	3.77	18.2	10.0	36.8

Graph 2: "Carbon" stock & sequestration potential in Cashew nut Orchards (MT)



RESULTS OF FINDINGS:

The total Carbon stock in Mango and Cashwnut orchards

Based on the estimated tree biomass, the total carbon stock above and below ground was estimated. The highest quantity of carbon stock was found in the Mango orchards. The estimated total carbon stock in woody biomass from Mango and Cashewnut orchards was 92 MT and was equivalent to 337 MT (Table 3). A study conducted by Shinde et al. (2015) in Satara district of Maharashtra state on carbon sequestration of some fruit trees. Carbon sequestration in mango (58.06 and 115.44 kg tree^{-1}), in 10- and 15-year-old trees. Carbon dioxide removed from the atmosphere was in mango (21.24 and 28.16 kg tree^{-1} year^{-1}), in 10 and 15-year-old tree. Total Carbon stock and sequestration potential in Mango and Cashewnut orchards estimated that the C stock in woody biomass was 7.7 MTha^{-1} and which was equivalent to 28.1 MTha^{-1} while the Carbon stock and sequestration potential including Soil was 34.2 MTha-1 and 125.4 CO_2e (Table-3). The study conducted by Nimbalkar et.al. 2017 estimated that the total above and below-ground biomass in a 10 year old agroforestry farm having amla or mango with forestry trees contained 23 MTha^{-1} of carbon which was equivalent to 84.67 MT CO_2 ha^{-1}. The carbon stock of the clear forest is 177.854 MTha^{-1}. While that of the cashew plantation is 8.6 MTha^{-1}, 66.3 MTha^{-1}and 193.3 MTha^{-1} respectively for plantations of 4, 10 and more than 10 years old. Our results have shown that cashew trees over 10 years old manage to recover and even exceed the rate of carbon lost after cutting down the clear forest. This study revealed that cashew farms can act as carbon sinks. These results make the species A. Occidentale a good candidate for reforestation, and land restoration to combat climate change and land degradation. (Kouadio et al. 2021)

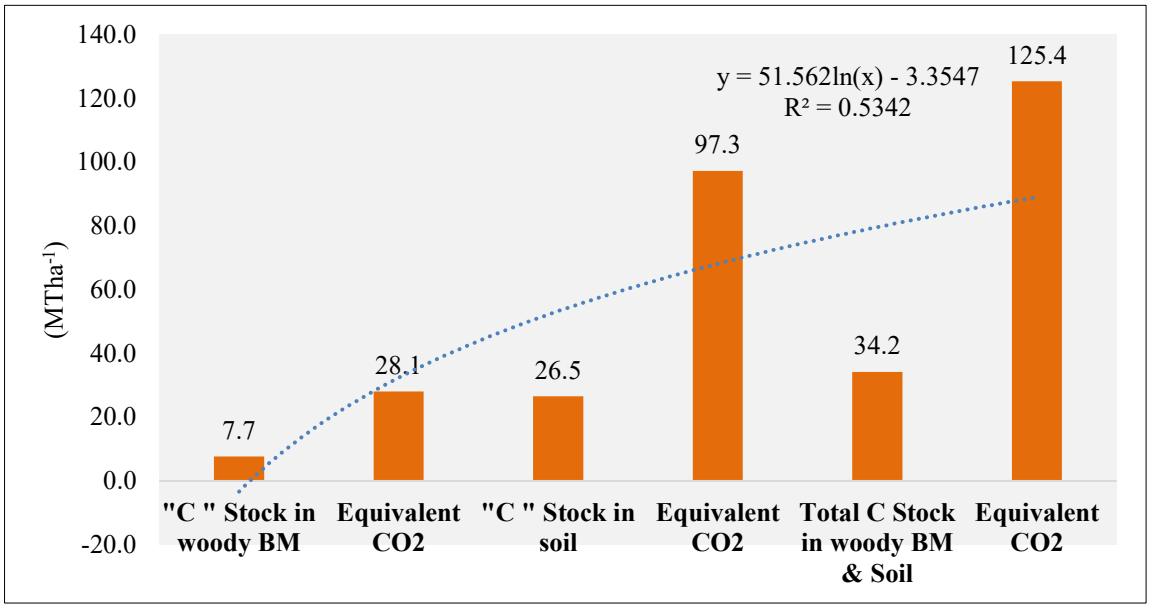
Table 3: Total Carbon stock and sequestration potential in Mango and Cashewnut orchards

Orchards	AGB (MT)	BGB (MT)	TBM (MT)	"C" Stock in BM (MT)	Equivalent CO_2 (MT)
Mango	73	19	91	50	184
Cashew	60	16	76	42	153
Total	133	34	167	92	337
Per ha (MT)	11.1	2.9	13.9	7.7	28.1

Graph 3: Total Carbon Stock and Sequestration Potential from woody biomass and Soil from Mango and Cashewnut Orchards

Conclusion:

In Mango orchards carbon stock in woody biomass at the age between 11 to 15 years old trees was 5.4



$MTha^{-1}$, which was equivalent to 19.6 $MTha^{-1}$ CO_2. Similarly at the age group between 16 to 20 years tree carbon stock in woody biomass was 11.4 $MTha^{-1}$ and which was equivalent to 41.8 $MTha^{-1}$ CO_2. In Cashewnut orchards carbon stock in woody biomass at the age between 11 to 15 years old trees was 3.8 $MTha^{-1}$, which was equivalent to 13.9 $MTha^{-1}$ CO_2. Similarly at the age group between 16 to 20 years tree carbon stock in woody biomass was 10.0 $MTha^{-1}$ and which was equivalent to 36.8 $MTha^{-1}$ CO_2.

It was concluded that the total Carbon stock and Sequestration potential in Mango and Cashewnut orchards including Soil carbon stock was 34.2 $MTha^{-1}$ and which was equivalent to 125.4 $MTha^{-1}$

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