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Ex-Ante Co-Benefit of Orchard Cropping as Climate Resilient Agriculture Practice in Drought Prone Area, Jalna District, Maharashtra, India

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ABSTRACT

A Project on Climate Resilient Agriculture (PoCRA) in drought prone regions of Maharashtra is intending to increase farm productivity and income of small land holding farmers. Horticulture plantation activity under project is one of climate resilient agriculture practice supported by PoCRA. About 93 farm plots of horticulture plantation and its co-benefits in Jalna district of Maharashtra have studied. A biomass estimation method was used for the measure of carbon sequestration. This method is essentially requiring plant density, height and girth diameter. It has observed that larger the plant biomass highest will be the carbon sequestered. Also, the number of plants per hectare has impact on biomass accounting. As per the observations, study shows highest to lowest carbon sequestration in plants in following order Pomegranate > Sweet lime > Mango > Guava > Custard apple i.e., respectively 66.38, 65.11, 33.24, 25.68 and 14.9 Kg of carbon sequestered per plant per year. This study primarily focuses on potential of carbon sequestration of horticulture plantation and ex-ante co-benefits in conservation of soil, water, nutrient. From the (PoCRA project) data it has observed that about 2215 ha of land is under fruit crop plantation (till September 2021) sequestering about 52,473.35 tons of CO2 per year. Also, it is expected that soil is conserve directly at these 2215 ha of orchard plantation plots, and 50% area covering drip irrigation conserve the water and nutrient, figured through farmer's application on portal i.e., for both drip irrigation and plantation. Therefore, it is benefitting farmers economically and sequestering carbon and conserving environment as co-benefit.

Keywords : Carbon Sequestration, Co-benefit, Orchard Plantation, Climate Resilient Agriculture

I. INTRODUCTION

A climate resilient agriculture system is a part of adaptation and mitigation measures towards climate change. It includes climate resilient seeds, water and nutrient management, improved agriculture practices to enhance soil organic carbon and increase farm productivity (World Bank; Srinivasrao et al., 2013).

However, carbon sequestration is the emission reduction by various means including management of environmental practices and policies in all sectors, commitment of renewable energy sources, optimum use of resources and recycling, and increasing the carbon sink (UNFCC). Ocean are the largest sink on the planet however, forest ecosystem is the biggest terrestrial carbon sink (Domke et. al., 2020). Sequestration of carbon is the process through which capture of carbon compounds for reducing GHG's effect on atmosphere (Kowalska 2020). Planting of trees is one of solution for increasing the terrestrial sink since it slows down the process of climate change and absorb the CO2 emitted (Carbon marketplace).

Fruit orchards are supplementary and continuous source of income to the farmers and act as insurance against crop failure. It maintains soil and water conservation and also form a biomass which stores carbon and increase soil organic carbon i.e., SOC (Ravindranath et al., 2012). Watering is done using drip saves water along with nutrients hence less input cost. Spacing between plants is convenient for pest management and optimum fertilizer application. Canopy covering the land area reduces soil exposure from sun hence soil moisture is retained helps in water stress conditions.

Afforestation activities are commonly implemented world-wide as part of climate action program (Hou 2019, Rajan et al., 2019). It is termed to be biological sequestration which involves forest, water, soil treatment so as to bind and accumulate carbon in ecosystem. Agriculture plays vital role for sequestration, since large areas under cultivation are managed for water, nutrient, tillage practice and the crop biomass etc. (Kowalska et al., 2020). In agriculture, fruit crop plantation activity is useful for the stock of large amount of carbon as plant biomass in tree trunk and branches (Rajan et al., 2019). It involves the process of photosynthesis which leads to conversion of CO2 into biomass in plants, hence plant tissue stored the carbon in aboveground and below ground biomass, dead cells or wood, flower, fruit, leaves and litter fall, etc. (Patil and Kumar 2017). Perennial horticultural crop plantation can sequester more soil carbon and enhance soil health than the annual or seasonal cropping pattern (Bhavya et. al., 2017).

Soil organic carbon (SOC) measured in various fruit crops by Zade et. al., (2017) showed that the presence of higher amount of SOC in perennial fruit orchards within same agroclimatic zones. Mango and Pomegranate are having highest SOC and were inferred on the basis of decomposition of leaf fall. Plant biomass is the widely accepted attribute in measuring carbon sequestration studied by Naik et. al., (2019) for mango plant in hot and sub-humid region of eastern India. The Gompertz model used in estimation of tree biomass showed 45-48% of biomass is stored in the trunk of plant are valid in collar diameter since it does not vary. Estimating carbon sequestration in agroforestry or forestry is common, however many researches towards carbon measure for fruit crops requires specific methodology (Rico et. al., 2016). There is no unique method for carbon sequestration estimation for fruit crops, hence in present study we are trying to estimate the potential of sequestration in the fruit crops in Jalna district using the plant biomass measure.

Jalna District present in the drought prone zone of Maharashtra has threatens the farmer due to unpredictable crop losses (Udmale et al., 2014). The fruit tree plantation will give rise to sustainability and additional income to farmers in such weather conditions. Similarly, it stands as a major carbon sequestration method for large areas. Hence, such study will benefit farmers for applying carbon credits to avail extra income from the polluting companies who are promoting carbon sequestration in open market.

Geography and Climate of the Jalna District: Jalna District located at the center of the state and geographically 19.1 to 20.3 North Lat to 75.4 to 76.4 East Longitude. As per census 2011, the district has total area of 7718 sq. km. and it is 2.51 % of the state area. Land use of Jalna showed 85% of area is under agriculture (Jalna.gov.in) and only 0.74% of area is covered with forest land (Achole 2014). Large area (95%) of Jalna is fall in Godavari River basin where Dudhana, Gulati and Purna are its major tributaries. Except to these river Khelna and Girija are flowing through the district. The major contingencies of the district are drought, flood, heat wave cold wave etc. (NICRA). Agriculture and horticulture are playing major role in economy of Jalna district. Fruit crop plantation such as sweet lime, guava, lime and pomegranate are the major horticulture crops in the district (NABARD). Average mean temperature of the district is 26 °C and average annual rainfall is 643-825mm (CGWB). The district is falling under semi-arid region and shows high frequency of droughts. A severe drought of 1972 resembles in year 2012 and hence more adaptation measures by farmer communities (Vedeld et. al., 2014).

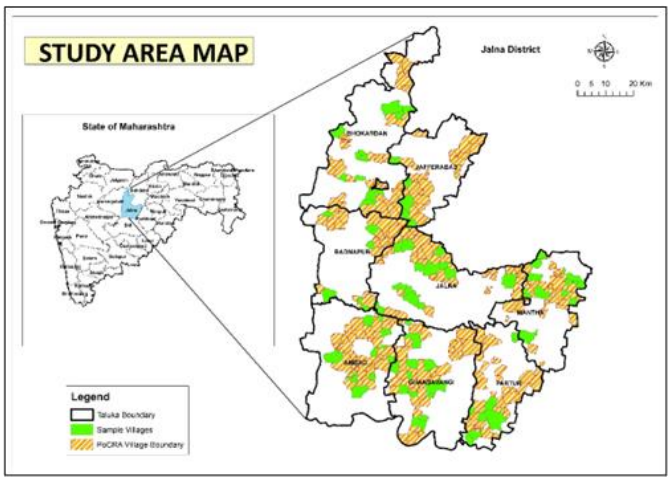

Fig. 1 Map showing Jalna District and PoCRA Villages

Data Collection and Methodology:

Primary Data: Google survey form created for data collection, the same was getting filled from farmers through cluster assistants (project staff) during month of December 2021. From the 362-village supported by PoCRA, about 93 farmers (farm plots) were selected who are direct beneficiary for fruit crop plantation.

Secondary Data: From the DBT portal area under fruit crop plantation, farmers, size of area and other requisite information was extracted using excel format.

Table 1: PoCRA Fruit Tree Plantation Guideline

Sr No.	Fruit Crop	Year of Cultivation	Area under Plantation in Ha	Distance	Number of plants per ha.
1	Custard Apple (Annona Squamosa)	2019-2020	18.06	5*5	400
2	Guava *(Psidium guajava)*	2019-2020	57.69	3*2	1666
3	Mango *(Mangifera indica)*	2019-2020	05.46	5*5	400
4	Pomegranate *(Pumica granatum)*	2019-2020	06.37	4.5*3	740
5	Lemon *(Citrus limon*) Oranges *(Citrus sinensis)* Sweet lime *(Citrus limetta)*	2019-2020	64.32	6*6	277

Source: Mahapocra.gov.in (Horticulture Plantation Guidelines)

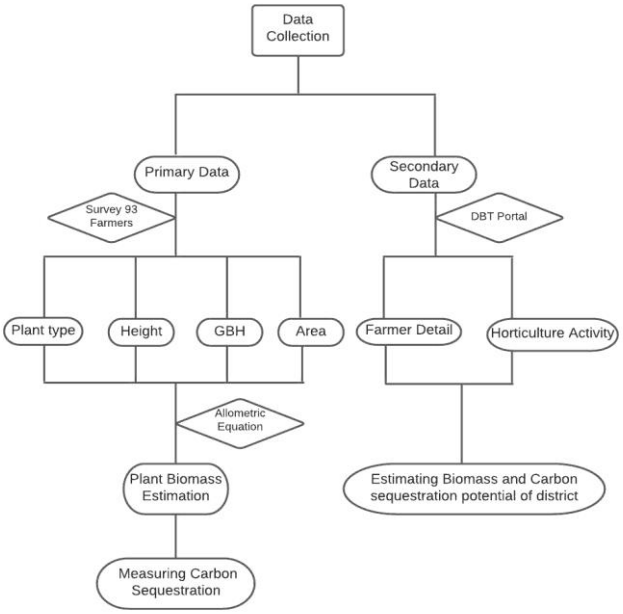

Fig. 2 Data Collection and Methodology

DBT – Direct Beneficiary Transfer

Sampling:

Total 93 fruit crop plantation plots (farmers) have been selected for primary data collection. After data collection validation of data were done from secondary data source i.e. DBT portal (Direct Beneficiary Portal) Maharashtra state portal of PoCRA. From the 93 farm plots sampled of five major plantations were Custard Apple (11), Guava (34), Mango (3), Pomegranate (5) and sweet lime (40). In Fig 3 Fruit plantation area in Ha. is presented.

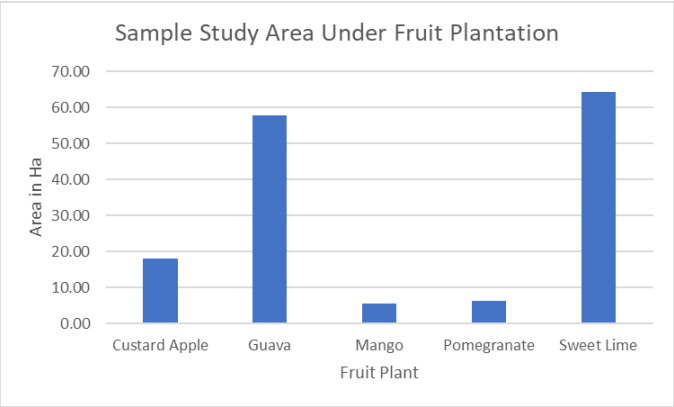

Fig. 3 Crop-wise plantation area in Ha

Measuring Plant height and Girth at Breast height: For measuring the height and the girth of plant in field rope and tape was used. Information filled in the google survey sheet in the field at the time of sampling. Plants average height were ranging from 4.8 ft to 5.2 ft. and average girth size was in between 6cm to 8cm. For the biomass estimation plant height and GBH are the essential parameters.

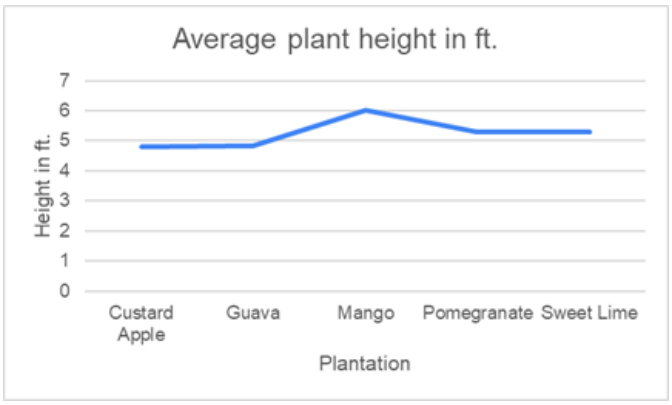

Fig. 4 Average plant height in feet

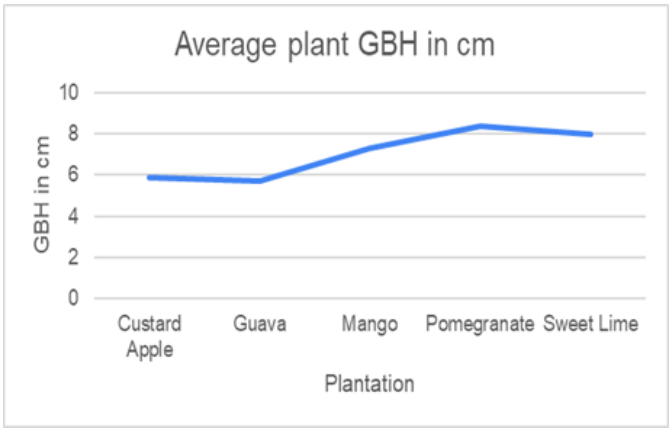

Fig. 5 Average Plant GBH in cm GBH-Girth at breast height

Calculating Carbon Sequestration: Indirect method of biomass index measure was used in present study requires data are plant height, girth diameter at breast height and wood density (Chaturvedi and Raghubanshi 2012, Biplab 2021). Wood density of trees has been taken from secondary researches shown in table no. 1. Hence, above ground mass, below ground mass and total biomass can be calculated to measure carbon sequestration in stipulated time period (Shinde et. al., 2015 and Eco-matcher).

Table 2: Plant Density

Sr. No.	Plant Common Name	Plant Density	References
1	Custard apple	360 Kg/m3	dwarffortress.com
2	Guava	674-676 Kg/m3	Lucas (2006), Shinde et. al., (2015)
3	Mango	680 Kg/m3	Shinde et al., (2015)
4	Pomegranate	770 Kg/m3	dwarffortress.com
5	Citrus	827 Kg/m3	Berti et al., (2018)

There are several methods for estimation of plant biomass, it helps to measure carbon sequestration. For measuring biomass, equations are developed by researchers in respective areas or regions (Biplab et al., 2021, Réjou et al., 2017, Ravindranath and Ostwals 2008). Using plant height and girth measure data carbon sequestration on study plots were measured (Shinde et al 2015, www.ecomatcher, www.unm.edu). Carbon sequestration is largely depends on tree species, wood density, climate in the region i.e. local conditions. Steps for measuring carbon sequestration as follow;

Step 1: AGB = D*H*WD

(AGB- Above Ground Biomass, D- girth diameter of the plant, H-Height of plant and WD- Wood density of the plant)

Step 2: BGB = 20% of AGB (BGB- Below Ground Biomass)

Step 3: TB = AGB + BGB (TB- Total Biomass)

Step 4: Weight of carbon is 50% of tree = 0.5* Dry weight of the tree

Step 5: Weight of carbon dioxide sequestred in the tree W carbon dioxide = 3.67*W of carbon (atomic weight of carbon in carbon dioxide molecule).

II. Result and Discussion

There are more than 2000 farmers benefitting from PoCRA particularly in tree plantation component. In present assessment potential of carbon sequestration and the ex-ante co-benefits arising from the fruit crop plantation in the Jalna district is measured and discussed. Assessment of total 93 plots with five major fruit crops in Jalna district were done in following table 3.

Table 3 : Measure of Fruit crop carbon sequestration for year 2021 and 2022 in Kg CO2

Crop with nos. of sample plots	Plant Avg. height in m	Plant Avg. diameter in m	Wood Density in Kg/m3	AGB Kg/tree	BGB 20% of AGB Kg/tree	TB in Kg/tree	Carbon in plant 50% of TB Kg/tree	Equivalent CO2	Carbon Sequestered per year Kg/tree
Custard Apple (11)	1.79	0.02	360	12.89	2.5776	15.47	7.73	28.38	14.19
Guava (34)	1.73	0.02	674	23.32	4.66408	27.98	13.99	51.35	25.68
Mango (3)	2.22	0.02	680	30.19	6.0384	36.23	18.12	66.48	33.24
Pomegranate (5)	2.56	0.03	770	59.14	11.8272	70.96	35.48	130.22	65.11
Sweet Lime (40)	2.43	0.03	827	60.29	12.05766	72.35	36.17	132.75	66.38

AGB- Above Ground Biomass, BGB- Below Ground Biomass, TB- Total Biomass

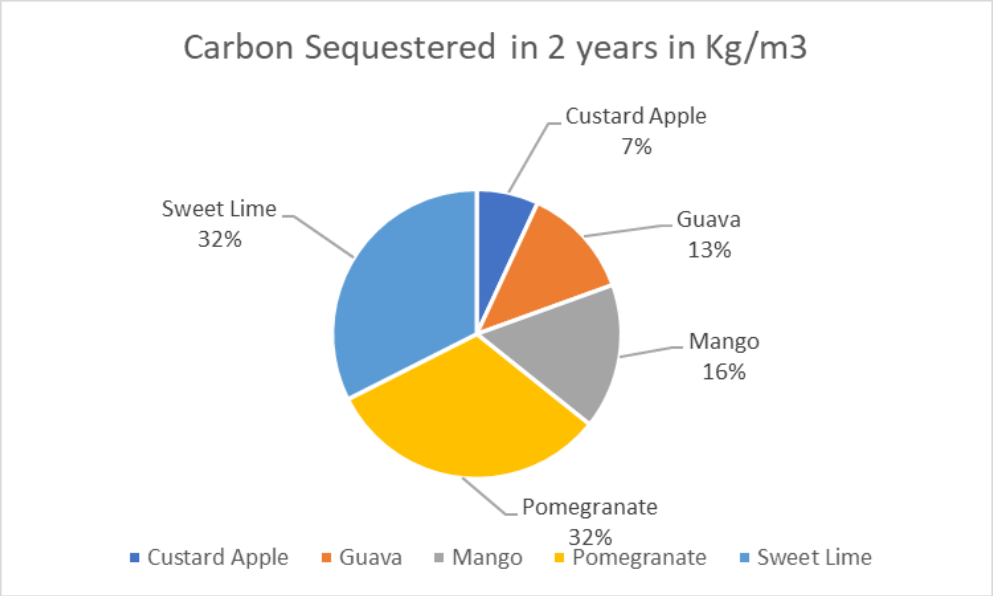

Fig: 6 : Percentage of CO2 Sequestered by fruit plants in past two year

Carbon Sequestration measure for the five different fruit plants in the present study showed that Pomegranate, Sweet lime and Mango has large potential of carbon sequestration. A plants girth size, height and wood density are more important in assessing the biomass of the plant, however the larger the size higher will be biomass and consequently the carbon sequestration potentials. Plants such as Guava and Custard Apple have less wood density, plants girth size and height at 2nd year hence less biomass estimated from the plants. An average of 13 Kg (Guava) to 58 Kg (Pomegranate) of carbon is sequestered per year by the plants. Since, every plant has different potential based on its location and other variables, eco-matcher research estimates around 25Kg of average CO2 sequestration per year, other study showed it is upto 70 Kg/year/tree (Sharma et. al., 2021). Carbon sequestered or stored is varying under different protected stages i.e., forest, protected forest, crop land or agroforestry etc. and the DBH (Martin et al., 2012). Sweet lime and Pomegranate plantation has highest percentage of CO2 sequestered in past two years however, the demand for horticulture plantation is specifically for Guava, Sweet lime and Custard apple plantation.

From the following table it can be estimated that the high number of plants per plot in the field has large carbon sequestration potential therefore, Guava and Pomegranate are having larger sequestration potential shown in table 4. Carbon sequestration per ha. is estimated based on the PoCRA horticulture plantation guidelines.

Table 4 : Fruit Crop plantation, number of plants, carbon sequestration per hectare per year

Sr. No.	Fruit Crop	Distance between plants	Number of plants	Plantation Plots	Ha of land under Plantation	Total nos. of Plants (as per guideline)	Carbon Seq. in Kg/m3 per plant per year	Carbon Seq. in Sampled Plots (for a Year) in Kg	Carbon Seq. Per Ha. In sampled Plots (for a year) in Kg	Carbon Seq. in Sampled Plots per Ha per year in Tones
1	Custard Apple	5*5	400	11	18.06	4400	14.19	62436.00	3457.12	3.46
2	Guava	3*2	1666	34	57.70	56644	25.68	1454617.92	25212.07	25.21
3	Mango	5*5	400	3	5.46	1200	33.24	39888.00	7299.61	7.30
4	Pomegranate	4.5*3	740	5	6.37	3700	65.11	240907.00	37798.82	37.80
5	Sweet Lime	6*6	277	40	64.32	11080	66.38	735490.40	11434.70	11.43

III. RESULTS AND DISCUSSION

Co-benefits arising from plantation of fruit crops: Co-benefits arising from the horticulture plantation are tangible and intangible in nature. Economic value from fruit (produce) selling, carbon sequestration, optimum utilization of land if intercropping is done etc. are tangible entities. However, intangible benefits are water and soil conservation on farm land. Fruit crop plantation under PoCRA is two/three years old,where fruiting to plant is not seen and hence direct economic benefits have not started at present, but the potential market value of the fruit produce coming will be expected to be high (Manilay et. Al., 2021). Present study shows large potential of carbon sequestration in project area due to horticulture plantation. Land preparation made for plantation is helping in restoration of soil, since once it is made it will be not disturbed for long time. Hence soils on this horticulture land are undisturbed and negligible losses from soil erosion, natural mulching due to leaf fall is additional benefit to the soil. Mango and pomegranate plantation are older in the region where drip irrigation activity mainly taken by the farmers. It increases optimum utilization of water resources on the field and ultimately more water is conserved and used in stress period.

Orchard cropping and climate resilience: Resilient, Robust and Reliable from aide to trade project in Kenya introduces 3R of climate resilient horticulture (Patrick et al., 2020). High temperature, precipitation can be leading to affect yield and quality of the crop produce. In drought prone regions orchard cultivation is a suitable option since it helps in water and nutrient management.

Conclusion: Based on the secondary data from PoCRA about fruit crop plantation in Jalna District, 5527 nos. of farmers are taking the benefit from the scheme and 6356 nos. of physical components are done through the same. A cost of 3322.44 lakh is disbursed for plantation till 30th Sep. 2021.

Therefore, it is estimated that on 2215 ha of land is under fruit plantation (average Rs. 150000 per ha disbursed). Considering per hectare carbon sequestration there is an average of 23.69 tones

(average of five fruit crop plantation)*2215 ha of land can sequester about 52,473.35 tonnes of CO_2 from the Jalna District of Maharashtra per year through PoCRA project.

PoCRA project is contributing in reduction of GHG by capturing CO_2, since plantation activity increase plant biomass. However, farmers are willingly come forward and take benefits of the scheme, in return their economy gets improved. Similarly, sustainable development goals can be achieved as it increases water harvesting potential in drought affected region and also reduces issues of poverty, hunger. Promotion of drip irrigation practice through fruit crop plantation is most important aspect of climate resilient agriculture. Global policies and program on climate change may help farmers in developing nations for reducing carbon emission. Hence, we can reduce the carbon foot print as well as farmers can get the additional benefits that will serve the purpose from local to global.

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