



## **Assessing the Carbon Sequestration Potential of Coconut Plantation in Vellore District of Tamil Nadu, India**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author KB objective formulation and overall guidance for the research work, wrote the protocol and wrote the first draft of the manuscript.*

*Author RJ designed the study and performed the statistical analysis, secondary data collection.*

*Author SK managed the analyses of the study and field experimental data collection. Authors RP and*

*SJ managed the literature searches, map generation and secondary data analysis. Author RJS validation of data analysis, grammar correction of manuscript. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Agriculture, very often falls victim of climate change around the world. Adopting a cost efficient system of agricultural production with minimal environmental impacts, depends on the selection of best cropping system and associated farming practices. The coconut farming and coconut agroecosystem is one of the country's largest agricultural systems and sectors that could substantially preserve carbon dioxide (CO<sub>2</sub>) through sequestration. Tamil Nadu state is one of the largest growers of coconut with an area of 443000 ha. In the present investigation the Vellore

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district was chosen as study area. Coconut data such as tree diameter and tree height were collected from the Tall (Aliyar nagar 1), Dwarf (Chowghat Orange Dwarf (COD)) and Chowghat Green Dwarf (CGD) varieties at different ages (five, fifteen, twenty and twenty-fifth years) at various plantations of Vellore district. The carbon sequestered by five, ten, fifteen, twenty and twenty-five-years old coconut tall variety trees were found to be 1.32, 1.97, 2.11, 3.10 and 3.96 tons per acre per year, respectively. Similarly, five, ten, fifteen, twenty and twenty-five-year-old coconut dwarf variety could able to sequester 1.45, 1.27, 1.58, 2.03 and 2.63 tons per acre per year, respectively in Vellore district. The C sequestration potential of ten year old coconut tree (Tall or Dwarf) were 18 to 28 kg per tree per year approximately. The fifteen years (2003-04 to 2017-18) coconut plantation of both tall and dwarf varieties in Vellore district had sequestered 1.15 million tons of carbon from the atmosphere.

**Keywords:** C sequestration; coconut plantation; dwarf; tall; climate change; Vellore.

## 1. INTRODUCTION

IPCC [1] revealed that the atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification. The global warming effects can be mitigated by reducing the greenhouse gas (GHG) emission and increasing the sequestration (storage) of C in the resources other than atmosphere.

Ecosystem play a key role for mitigating the climate change effects by fixing carbon from the atmosphere and storing it in the form of organic matter. The C sequestered in the ecosystem is the amount of carbon removed from the atmosphere and stored in ecosystem over the period of time [2]. Increase in atmospheric carbon dioxide concentration at 0.5 per cent per year accounts for about 3.2 Picagram (Pg) of carbon (C) per year and it is estimated that 2.0 Pg C per year is engrossed by the ocean. The remaining 1.8 Pg C per year is unaccounted and is believed to be absorbed by the terrestrial ecosystems.

Soil contains approximately three times more C than the atmosphere and four and half times more carbon than all living beings. A big unknown in this global C balance is the role of the world soils in carbon emission and sequestration [3]. Carbon sequestration refers to the removal of carbon dioxide from the atmosphere into a long-lived stable form that does not affect atmospheric chemistry [4]. Thus, identifying viable sinks is high priority with the

objective of sequestration into various passive pools of C with long residence time.

The options of CO<sub>2</sub> sequestration being considered are geologic, oceanic, chemical transformations and terrestrial. Among these, the carbon capture by terrestrial sequestration is a natural process with ancillary benefits besides cost-effectiveness [5]. Amount of CO<sub>2</sub> produced by anthropogenic activities exceeded the best estimates of CO<sub>2</sub> absorbed by ocean and atmosphere. To account for this budget imbalance, there must be another large CO<sub>2</sub> sink and was identified as the world's terrestrial plants and soils [6]. The plantation crops being a perennial nature play a key role in the terrestrial carbon sequestration by efficiently converting the CO<sub>2</sub> into huge biomass besides improving the soil C pools.

The potential of carbon sequestration in a coconut plantation may vary with age, cultivar, soil fertility, agro-climatic condition, management practices and type of intercrop. The net ecosystem carbon exchange of a twenty-year old coconut plantation grown under near-optimal conditions (high fertility, no drought, high yielding variety) in Santo, Vanuatu was 4.7 – 8.1 t C ha<sup>-1</sup> yr<sup>-1</sup> [7]. The coconut plantation with intercropping with baby corn, cucumber and tomato sequester 16.13 t ha<sup>-1</sup> Soil C compared to 14.48 to 16.13 t ha<sup>-1</sup> in the mono cropping of coconut [8]. The highest total carbon stock was observed in coconut + jamun system (140.06 t/ha) followed by coconut + mango (138.91 t/ha) and coconut + garcinia (131.72 t/ha) system and lowest carbon stock was recorded in coconut monocrop total C stock (98.2 t/ha) [9].

The clean development mechanism (CDM) presents an opportunity for developing countries to get certified emission reductions for negotiations in the carbon market. Productivity

and carbon balance of each type of land use are key issues for Clean Development Mechanism (CDM), particularly under the tropics. In addition, the impact of crop management on GHG emissions might become an issue under the second period of commitment of the Kyoto Protocol (>2012) [7].

India is one of the leading coconut growing nations with a production of about 15.73 billion nuts from an area of 1.89 million ha at an average productivity of 8300 nuts per hectare per year [10]. In Tamil Nadu coconut is grown in an area of 443000 hectares, in which Vellore district occupy an area of 27,974 hectare [11]. Coconut cultivation continue to be an important livelihood for about 10 million people in India. Hence in this paper we assessed the climate change mitigation potential of coconut plantations through carbon sequestration by various age groups and variety (Tall and Dwarf) in Vellore District of Tamil Nadu.

### 1.1 Study Area

Vellore district lies between 12° 15' to 13° 15' North latitudes and 78° 20' to 79° 50' East longitudes in Tamil Nadu State (Fig. 1). The geographical area of this district is 6077 sq. km. The data on tree diameter and height were collected from four villages namely Mittur, Andiyappanur, Irrunapattu and Poongulam in Vellore district, Tamil Nadu. Since, these villages represents various size holdings and coconut based system.

## 2. MATERIALS AND METHODS

### 2.1 Carbon-di-oxide Sequestration Potential of Coconut Tree

Studies shows coconut grown in tropical climates will sequester atmospheric carbon dioxide at an average amount of 50 pounds of carbon dioxide

per tree per year. The rate of carbon sequestration depends on the growth characteristics of the tree species, the growing conditions and the density of wood in tropical region [12].

### 2.2 Determining the Total (Green) Weight of the Tree [13]

Based on tree species in the Southeast United States, the algorithm to calculate the weight of a tree is:

$$\text{For trees with } D < 11 : W = 0.25 D^2 H$$

$$\text{For trees with } D \geq 11 : W = 0.15 D^2 H$$

Where,

W = Above-ground weight of the tree in pounds.

D = Diameter of the trunk in inches.

H = Height of the tree in feet.

Depending on the species, the coefficient (e.g. 0.25) might change and the variables  $D^2$  and H, could be raised to exponents just above or below. However, these two equations could be seen as an “average” of all the species’ equations. The root system weighs about 20% of the above-ground weight of the tree. Therefore, to determine the total (green) weight, taking all species into account, the average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, the weight of the tree was multiplied by 72.5%.

### 2.3 Determining the Carbon Content in the Tree

The average carbon content is generally 50% of the tree’s total volume. Therefore, to determine the weight of carbon in the tree, the dry weight of the tree has to be multiplied by 50%.

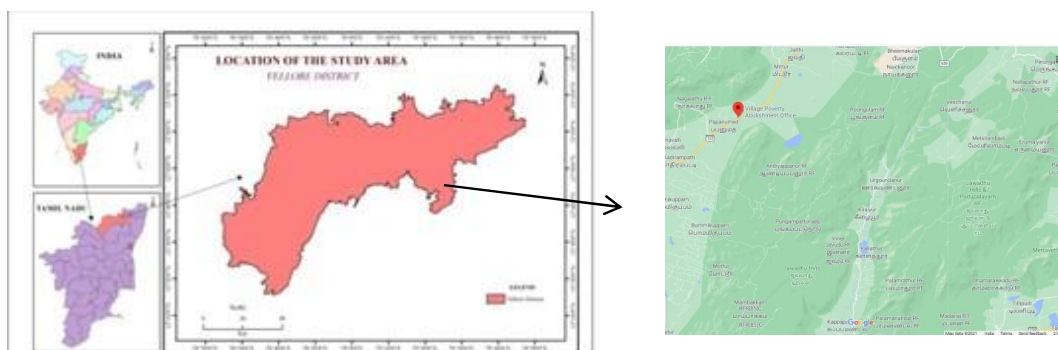


Fig. 1. Study area map, Vellore, Tamil Nadu, India

## 2.4 Determining the Weight of Carbon Dioxide Sequestered in the Tree

The method proposed by Badwal and Singh [14] was adopted in this study. CO<sub>2</sub> is composed of one molecule of carbon and two molecules of oxygen. The atomic weight of carbon and oxygen is 12.001115 and 15.9994, respectively. Hence, the weight of CO<sub>2</sub> is C+2\*O = 43.999915. The ratio of CO<sub>2</sub> to C is 43.999915/12.001115 = 3.666. Hence, to determine the weight of carbon dioxide sequestered in the tree, the weight of carbon in the tree is multiplied by 3.6663.

## 3. RESULTS AND DISCUSSION

The rate of carbon sequestration depends on age of the tree, density of the stem, growing conditions and associated plantation management. The average lifespan of tall (Aliyar Nagar – 1) variety is nearly 80 to 90 years and for the dwarf variety (Chowghat orange Dwarf (COD) and Chowghat Green Dwarf (CGD) is 40-50 years. Generally carbon sequestration is highest during in young plantations.

### 3.1 Height of the Coconut Tree

The plant height is needed for calculating total green weight of the palm and the height will vary with variety and time. The total height of the tall variety and Dwarf varieties at five, ten, fifteen,

twenty and twenty-fifth year old were measured and are presented in the Table 1. The average height of of five, ten, fifteen, twenty and twenty-fifth year old tall and dwarf variety trees are 6.5, 10.9, 15.2, 22.0, 29.0 and 5.3, 9.2, 13.8, 18.6, 23.3 feet respectively.

### 3.2 Total (Green) Weight of the Coconut Tree

The total green weight including the root system of the palm was calculated considering the age of the plantation, girth of the stem, height of the tree and type of palm. The total weight of the tall variety at five, ten, fifteen, twenty and twenty-fifth year old were calculated and are presented in the Table 1a. The potential green weights of five, ten, fifteen, twenty and twenty-fifth year old tall and dwarf variety trees are 70, 208, 336, 675, 1048 and 77, 135, 251, 430 and 696 Kg per tree respectively.

### 3.3 Dry Weight of the Coconut Tree

The dry weight of the coconut tree is calculated from the total green weight of the tree considering the water content of palm. The dry weights of coconut tree are presented in Table 2. The dry weight of tall variety vary from 53 kg/tree at the age of 5 years to 760 kg/tree at the age of 25 years. Similarly, the weight of dwarf varieties range from 56 kg/tree to 505 kg/tree.

Table 1. The height of the coconut tree

S. No.	Age of the tree (Year)	Tall variety	Dwarf variety
		Average height in feet	
1	5	6.5	5.3
2	10	10.9	9.2
3	15	15.2	13.8
4	20	22.0	18.6
5	25	29.0	23.3

Table 1a. Total green weight of the coconut tree

S. No.	Age of the tree (Year)	Tall variety	Dwarf Variety
		Green weight of the tree (Kg/tree)	
1	5	70	77
2	10	208	135
3	15	336	251
4	20	657	430
5	25	1048	696

**Table 2. The Dry weight of the coconut tree**

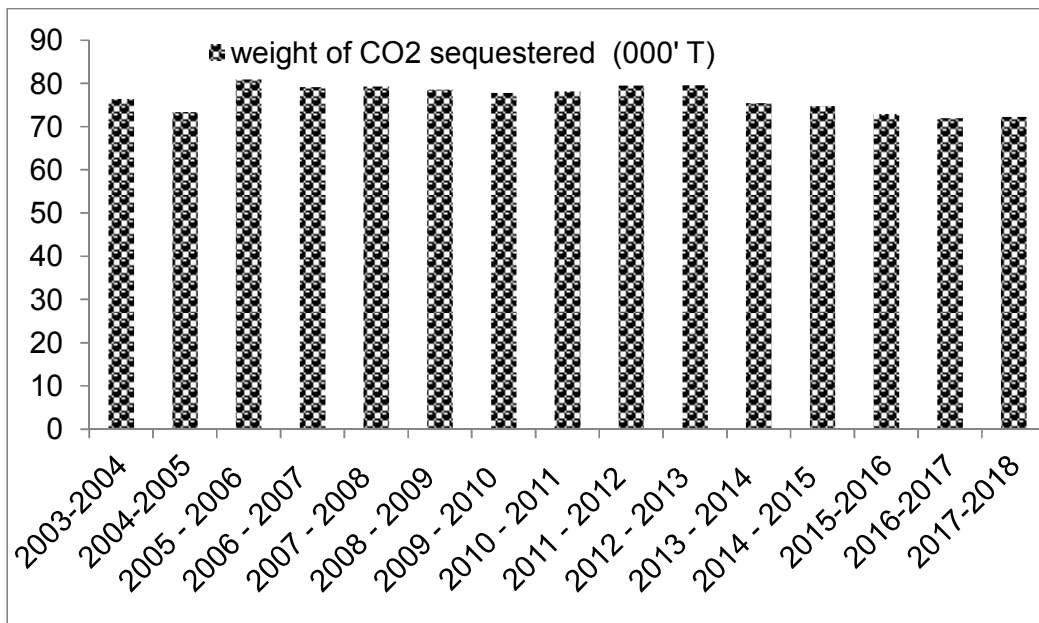
S. No.	Age of the tree (Year)	Tall variety	Dwarf variety
		Dry weight of the tree (Kg/tree)	
1	5	53	56
2	10	151	98
3	15	243	182
4	20	476	312
5	25	760	505

**Table 3. The weight of Carbon in the tree**

S. No.	Age of the tree (Year)	Tall variety	Dwarf variety
		Weight of Carbon in the tree (Kg)	
1	5	25	28
2	10	76	49
3	15	122	91
4	20	238	156
5	25	380	252

**Table 4. The weight of CO<sub>2</sub> sequestered in the tree per year**

S. No.	Age of the tree (Year)	Tall variety	Dwarf variety
		Weight of CO <sub>2</sub> sequestered in the tree/year (Kg)	
1	5	19	20
2	10	28	18
3	15	30	22
4	20	44	29
5	25	56	37



**Fig. 2. Year wise carbon di oxide sequestered by coconut plantation in Vellore district**

\*Note: Approximately 10-year-old Coconut tree (Tall or Dwarf) carbon sequestration potential are 18-28 Kg/ Tree/ Year. Average value we have taken is 20 Kg/ Tree/ Year for calculation

### 3.4 Weight of Carbon in Coconut Tree

The weight of carbon is calculated from the dry weight of the tree (Table 3). The carbon accumulation potential of the tall variety varies from 25 kg per tree at the age of 5 years to 380 kg/tree at the age of 25 years. The dwarf variety accumulate 28 kg/ tree at the age of 5 years to 252 kg at 25 years of age.

### 3.5 Carbon Dioxide Sequestration Potential of Coconut Tree

The amount of CO<sub>2</sub> sequestered in the tree per year is calculated from weight of carbon in tree and weight of CO<sub>2</sub> sequestered in the tree (Table 4).

The weight of CO<sub>2</sub> sequestered in the tree per year calculated using the weight of CO<sub>2</sub> sequestered in the tree. Nearly, 19, 28, 30, 44 and 56 Kg per tree of CO<sub>2</sub> is sequestered during fifth, tenth, twentieth and twenty fifth year old tall variety. The weight of CO<sub>2</sub> sequestered by the five, ten, fifteen, twenty and twenty-fifth year old dwarf variety trees are 20, 18, 22, 29 and 37 Kg per tree.

### 3.6 CO<sub>2</sub> Sequestration in the Tall and Dwarf Variety Coconut Tree

Coconut plantation with tall variety in five, ten, fifteen, twenty and twenty-five-year-old sequestered 1.32, 1.97, 2.11, 3.10 and 3.96 tons/ acre/ year of carbon respectively from the atmosphere. Similarly coconut plantation with dwarf variety in five, ten, fifteen, twenty and twenty five year old sequestered 1.45, 1.27, 1.58, 2.03, and 2.63 tons/ acre/ year of carbon respectively from the atmosphere.

### 3.7 CO<sub>2</sub> Sequestration in Coconut Plantation in Vellore District

The amount of carbon sequestered during a period of fifteen years in Fig. 2. The period of study considered was 2003 to 2018 (15 years). During the period of 15 years coconut plantation in Vellore district sequestered carbon, which vary from 76479 t during 2003-04 to 72295 t during 2017-18. Thus, coconut plantation in Vellore district sequester 1.15 million tonnes of CO<sub>2</sub>, which accounts for an average of 20 kg per tree per year.

## 4. CONCLUSION

The Carbon sequestration into organic matter is one the most important practical solution

arguably contributing to the limitation of the current increase in atmospheric carbon dioxide. From our study, the average carbon sequestration achieved by Coconut trees is comprised between 37 kg/tree/year (the "Dwarf" variety) up to 56 kg/tree/year (the "Tall" variety). Accordingly, the cumulated contributions of Coconut trees (both Tall and Dwarf varieties) to carbon sequestration is estimated around 1.15 million tons, just by considering Vellore district only. Since, the coconut tree has high gross primary productivity (GPP) and net primary productivity (NPP) and the coconut tree will not behave like dicot, it diverts most of its photosynthetic product to leaves, fruits, peduncle and fine roots, which are perishable in nature. Hence, most of this perishable material would be decomposed by microbes and convert in to Soil Organic Matter (SOM). Though the coconut plantation is closely act like a tropical evergreen broad leaf forest, it has highest potential of sequestering carbon, apart from providing continuous monetary benefits to farmer, hence, there is a need to evaluate the potential and provide carbon credit certification. At the present system of coconut farming with better management strategies and with suitable intercropping the coconut plantations can be effectively considered as a potential C sequestration source to mitigate the climate change problems.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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