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Assessing the climate change mitigation potential of coconut plantation in Dindigul district of Tamil Nadu

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Abstract
Greenhouse gases (GHGs) are ceaselessly increasing in the atmosphere leading to climate change. Capturing and storing carbon by adopting a suitable agricultural practice is of the effective method of carbon sequestration. Dindigul, is one of the leading coconut producing districts of Tamil Nadu covering an area of 31,507 ha. Samples were collected from the Tall (Aliyar Nagar 1) and Dwarf (Chowghat Orange Dwarf (COD)) and Chowghat Green Dwarf (CGD) varieties during different ages (five, fifteen, twenty, and twenty-fifth year). The carbon sequestered by five, ten, fifteen, twenty and twenty five year old coconut tall variety trees were 1.91, 2.55, 2.91, 3.40 and 3.83 tons acre^{-1} year^{-1}. Similarly five, ten, fifteen, twenty and twenty five year old coconut dwarf variety could able to sequester 0.92, 0.78, 1.27, 1.98 and 2.48 tons acre^{-1} year^{-1} in Dindigul district. The carbon sequestration potential of ten year old coconut tree (Tall or Dwarf) were 18 to 28 kg acre^{-1} year^{-1} approximately. The fifteen years (2003 to 2018) coconut plantation of both tall and dwarf varieties in Dindigul district had sequestered was 1463652 tonnes of carbon di-oxide from the atmosphere.

Keywords: Dindigul, coconut, tall variety, dwarf varieties, carbon sequestration

Introduction
Changes in the climate are related to a rise in greenhouse gas (GHG), which increases the global greenhouse effect in the atmosphere. The most important contributor to the anthropogenic greenhouse effect is carbon di-oxide (CO_2) (Ranasinghe and Thimothias, 2012) [17]. The regulation of the excess of atmospheric CO_2 and other GHGs is a major concern to minimize the risk of global warming (Kerr, 2007) [7]. Enhanced greenhouse effects can be alleviated by reducing emissions of GHG and rising carbon sequestration. Carbon sinks may play an important role in the global carbon cycle and climate change mitigation. A rise of 0.5 percent annually in atmospheric carbon dioxide corresponds to about 3.2 Pg carbon and it is estimated that ocean are the major sink engulfing around 2.0 Pg per year C. The remaining 1.8 Pg C is not counted every year and is expected to reach the terrestrial ecosystem. Soil contains about three times the carbon in the atmosphere and 4.5 times the carbon in all life. The role of the global soil for carbon emission and sequestration processes, in particular, are a key unknown factor in this global C balance (Lal *et al.*, 2007) [12]. Carbon sequester is a stable process that has no effect on atmospheric chemistry, and absorbs ambient carbon dioxide (Miller *et al.*, 2002) [13]. The discovery of viable sinks is therefore a top priority in order to sequestrate various passive C pools with a long residence period. Geological, oceanic, chemical and terrestrial transformations are the various CO_2 sequestration methods. Among such, terrestrial sequestration carbon capture is a natural process with additional benefits in addition to cost-efficiency (Lal, 2008) [11]. The terrestrial carbon cycle includes the fixation of atmospheric CO_2 by plant through photosynthesis, the distribution of photo assimilated carbon into plant and animal pools and the integration of plant, animal and other sources of carbon into soil-organic matter through residue degradation and re-synthesis (Stevenson, 1994). Plantation crops play a crucial role in the sequestration of land-based carbon by turning CO_2 into big biomass and enhancing the soil-C reservoirs efficiently. The potential of carbon sequestration in a coconut plantation may vary with age, cultivar, cover crop, inter-crop, soil

fertility, agro climatic condition, management practices and type of intercrop. However, such information of coconut plantations is scarce. 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 Cha^{-1} yr^{-1} (Roupsard *et al*., 2008) [18]. In India, the values were reported as 8 – 32 t CO_2 ha^{-1} yr^{-1} (equal to 2 – 9 t C ha^{-1} yr^{-1}) (Anonymous, 2008). Bhagya *et al.* (2017) [4] has reported a sequestration potential of 51.14 C t^{-1} ha^{-1} by coconut plantation at Kasargod, Kerala. Ranasinghe and Thimothias (2012) [17] have stated that coconut plantation has to potential to sequester carbon and the net carbon exchange rates ranging from 0.4-1.9 Mg C ha^{-1} $month^{-1}$. The clean development mechanism (CDM) presents an opportunity for developing countries to get certified emission reductions for negotiations in the C market. Productivity and carbon balance of each type of land use in coconut are key issues for the CDM (Roupsard *et al*., 2008) [18].

India is one of the leading coconut growing nations with a production of about 15.73 billion nuts from an area of 1.89 M ha at an average productivity of 8300 nuts ha^{-1} (CDB, 2018) [5]. The four largest coconut production states, Kerala, Tamil Nadu, Karnataka & Andhra Pradesh, account for over 90% of the production and area (Bhagya *et al.*, 2017) [4]. Dindigul is one of the major coconut producing district in Tamil Nadu covering an area of 31,507 ha (Balaji Kannan *et al.*, 2017) [3]. All three types of coconut plantations are present in India, which provide livelihood sustenance to about 10 million people. Scientific studies on the potential of carbon sequestration by coconut plantation in Tamil Nadu are scarce. Therefore, the main objective of this study is to identify the carbon sequestration potential of coconut plantation in Dindigul at different ages (five, ten, fifteen, twenty and twenty five years old) of two different varieties (tall and dwarf) respectively.

Materials and Methods

Location, climate and variety

Dindigul, lying between 10.05' and 10.9' North latitude and 77.30' and 78.20' East longitude, experiences semi and tropical monsoon in the plains and fairly heavy rainfall in the upper Palani hills and is one of the leading coconut growing district of Tamil Nadu (Fig. 1). The maximum and minimum temperature in the plains is 37.5 and 19.7 °C whereas, in the hills, it is 20.6 and 7.7°C respectively. Loamy and clayey are the predominant soil type found in these regions. It covers an area of 6266.64 sq. km. holding a population of 2159775 (2011 Census). Samples were collected from five villages namely Oddanchatram, Athicombai, Lakkayankottai, Palani and Boduvarpatti respectively. A tall variety (Aliyar Nagar – 1), two dwarf varieties (Chowghat Orange Dwarf (COD) and Chowghat Green Dwarf (CGD)) were studied at different age (5, 10, 15, 20 and 25 years).

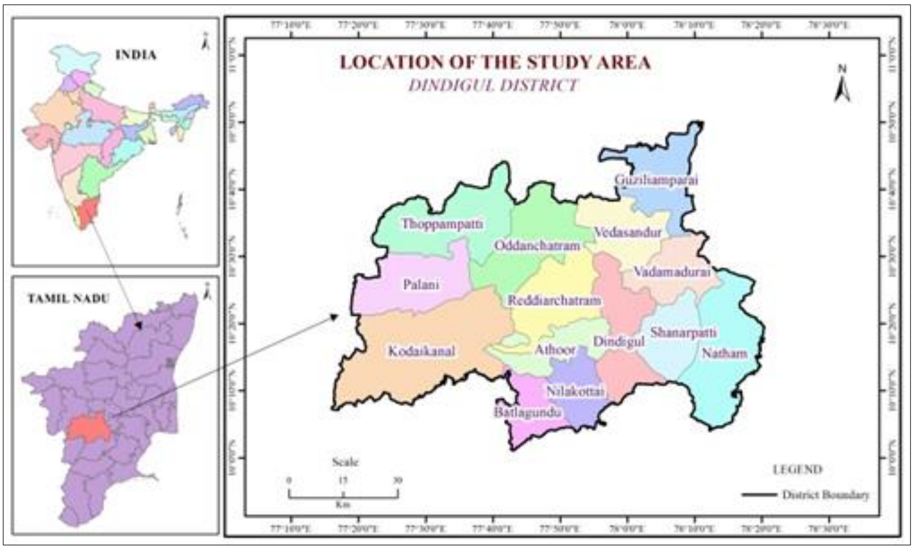


Fig 1: Study area

Quantification of CO_2 sequestered by coconut

The trees planted in tropical climates, will sequester atmospheric carbon di-oxide at an average of 50 pounds of carbon di-oxide $tree^{-1}$ $year^{-1}$. The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. The sequestration potential is higher during its younger stages of tree growth, *viz.*, between 20 to 50 years.

Total (green) weight of the tree

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

For trees with D < 11: $W = 0.25 D^2H$ For trees with D >= 11: $W = 0.15 D^2H$

W = Above-ground weight of the tree in pounds

D = Diameter of the trunk in inches

H = Height of the tree in feet

The coefficient (e.g. 0.25) can change, depending on the species and the D^2 and H variables may be elevated to above or below exponents. But these two equations may be considered to be an "average" of the equations of all species. The weight of the root system is approximately 20% of the tree’s above ground biomass. Hence, the moisture content of the tree is 27.5% and the remaining is its dry weight. Accordingly, in order to calculate the dry weight of the tree, the weight of the tree must be multiplied by 72.5% (Alexander Clark III *et al.*, 1986) [1].

Carbon content of the tree

The average carbon content is typically 50% of the total volume of the tree. The dry weight of the tree must therefore be raised by 50% to calculate the weight of carbon in the tree. (Alexander Clark III *et al.*, 1986) [1].

Amount of carbon di-oxide sequestered by the tree
CO_2 consists of a single carbon molecule and two oxygen molecules. Carbon and oxygen have an atomic weight of 12.001115 and 15.9994 respectively. Consecutively, the weight of CO_2 is 43.999915 and ratio of CO_2 to C is 3.666. Therefore, the weight of the carbon in the tree has to be multiplied by 3.6663 in order to assess the amount of carbon di-oxide sequestered (Badwal and Singh, 2002) [2].

Weight of CO_2 sequestered in the tree per year
The annual weight of carbon di-oxide sequestered by the tree is determined by dividing the CO_2 sequestered by the age of the tree. (Badwal and Singh, 2002) [2].

Results
The rate of carbon sequestration is dependent on growth attributes such as age, growth conditions and stem density of the tree, respectively. Sequestration is at its peak during the younger stages. For tall (Aliyar Nagar – 1) and dwarf (Chowghat orange Dwarf (COD) and Chowghat Green Dwarf (CGD)) variety, the average lifespan is 80 – 90 and 40 – 50 years respectively.

Total (green) weight of the coconut tree
The total green weight along with the root system is calculated by considering the age, height, type of the tree and the stem's girth. The total green weight of the tall and dwarf variety are given in Table 1. Total green weight of the tall and dwarf variety of five, ten, fifteen, twenty and twenty-five years are 102, 275, 464, 724, 1010 and 47, 82, 209, 417 and 657 kg respectively.

Table 1: The Total Green weight of the tree (W)

Age of the tree (Year)	Tall variety	Dwarf Variety
	Green weight of the tree (W) (kg)	
5	102	47
10	275	82
15	464	209
20	724	417
25	1010	657

Dry weight of the coconut tree
Table 2 represents the dry weight of the cocoon tree by eliminating its moisture content from the tree's total green weight. The dry weight of the tall variety ranges from 74 to 733 kg tree^{-1} at age 5 and 25 years respectively. Likewise, the dwarf species also have weights ranging between 34 and 476 kg tree^{-1} at age 5 and 25 years respectively.

Table 2: Dry weight of the tree

Age of the tree (Year)	Tall variety	Dwarf variety
	Dry weight of the tree (kg tree^{-1})	
5	74	34
10	199	59
15	336	151
20	525	302
25	733	476

Carbon weight of the tree
The carbon weight in the tree has been determined from its dry weight (Table 3). The ability of tall variety to accumulate carbon is relatively higher and ranges from 37 kg tree^{-1} at age 5 to 366 kg tree^{-1} at age 25. At the age of 5, the dwarf variety accumulates 17 kg tree^{-1} and 238 kg tree^{-1} at age 25 respectively.

Table 3: Carbon weight in the tree

Age of the tree (Year)	Tall variety	Dwarf variety
	Weight of Carbon in the tree (kg tree^{-1})	
5	37	17
10	100	30
15	168	76
20	262	151
25	366	238

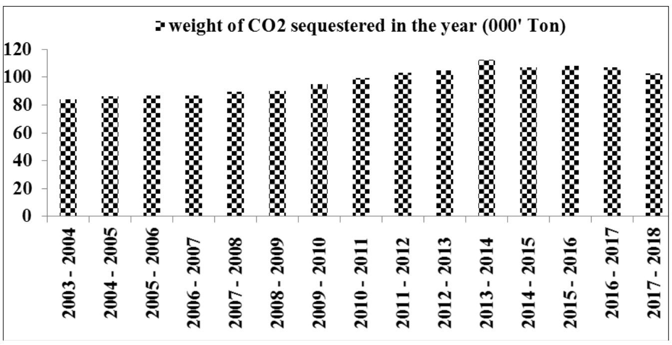
Weight of CO_2 sequestered in the tree per year
The weight of CO_2 sequestered per year in the tree was determined by the weight of CO_2 sequestered and age of the tree. Annually, the 5, 10, 15, 20 and 25 years old tall variety sequesters 27, 36, 41, 48, 54 kg tree^{-1} year^{-1} and similarly, the dwarf variety sequesters 13,11,18,28 and 35 kg tree^{-1} year^{-1} respectively (Table 4).

Table 4: The weight of CO_2 sequestered in the tree per year

Age of the tree (Year)	Tall variety	Dwarf variety
	weight of CO_2 sequestered in the tree^{-1} year^{-1} (kg)	
5	27	13
10	36	11
15	41	18
20	48	28
25	54	35

CO_2 Sequestration by Coconut plantation in Dindigul district
The carbon sequestered by five, ten, fifteen, twenty and twenty five year old coconut tall variety trees were 1.91, 2.55, 2.91, 3.40 and 3.83 tons acre^{-1} year^{-1} (Fig. 2). Similarly five, ten, fifteen, twenty and twenty five year old coconut dwarf variety could able to sequester 0.92, 0.78, 1.27, 1.98 and 2.48 tons acre^{-1} year^{-1} in Dindigul district.

The carbon di-oxide sequestered during our study period of fifteen years (2003 – 2018) is given in Fig.1. During the study period, the amount of carbon di-oxide sequestered ranges from 84132 to 112479 tonnes during 2003 – 04 and 2013 – 14 respectively.



*__Note:__ Approximately 10 year old Coconut tree (Tall or Dwarf) has a carbon sequestration potential of 18-28 kg tree^{-1} year^{-1} with an average of 20 kg tree^{-1} year^{-1} for calculation.

Fig 2: Carbon di-oxide sequestered by coconut plantation in Dindigul

Overall, for every ten years the coconut plantation sequesters nearly 8353 million tons of carbon of atmosphere thereby validating its potential and vital role in mitigating climate change in Dindigul district.

Discussion

Many studies indicate that tree plantation are exceptional carbon pools on the basis that trees, coconut especially, have a much greater carbon content per unit area than other forms of vegetation (Ranasinghe and Silva, 2007). However, many of these studies are too general and not focused on scientifically validated study. Detailed research on net primary productivity (NPP) on coconut plantation is rare. The total annual production of biomass from sole coconut stand with 175 adult (in full bearing stage) palms was estimated by Nelliat *et al.* (1974) at a range of 14.2 Mg ha^{-1} at an annual average production level of 60 coconuts per palm, 18.7 Mg ha^{-1} at 100 nuts, and at a very high production level of 250 nuts up to 35.5 Mg ha^{-1}. Another study has reported that the dry matter production of coconut is 52 – 62 Mg ha^{-1} $year^{-1}$ (Kumar *et al.*, 2008; Corley *et al.*, 1983) [10, 6]. The aboveground C stock of diverse tree species with coconut and several other fruit trees of various stand densities in south western coast of India was found to be varying from 16.3 – 35.2 Mg ha^{-1} (Kumar and Takeuchi, 2009 and Kumar, 2011) [9, 8]. Navarro *et al.* (2008) [14] deduced the high productivity of coconut plantation, typical of tropical humid evergreen forest ecosystems, from the reported values of NPP. Roupsard *et al.* (2008) [18] stated that the maximum bearing stage of coconut is normally achieved with adequate nutrition for seven years (dwarfs), 10 years (hybrids), and 12 years (talls). Naveen Kumar and Maheswarappa (2019) [15] has reported that intercropping of coconut plantation with vegetable crops have significantly promoted the aboveground and belowground carbon stock.

Conclusion

The photosynthetic rate (gross primary productivity) and net primary productivity (NPP) in the coconut tree is high. The coconut tree store most part of its photosynthesis into perishable parts such as leaves, fruit, peduncles and fine roots. Most of this peregrinated material will therefore be decomposed by microbes and converted into soil organic matter (SOM). While coconut farm is closely related to a tropical evergreen broad leaf forest, it has the maximum carbon sequestration capacity, and in addition to providing farmers with continuous monitory benefits, the ability and supplier of carbon certification needs to be evaluated. Intercropping and better management practices have to be assessed, thereby increasing agricultural productivity and mitigating climate change. Future studies are required to identify the CO_2 sequestration potential of age old trees (> 40 – 50 years) in order to screen the approximate age for maximum sequestration.

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