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

K Boomiraj, R Poornima, R Mohammaed Umar, K Senthilraja, R Jude Sudhagar and R Jagadeeswaran

DOI: https://doi.org/10.22271/chemi.2021.v9.i2e.11823

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 (Allyar 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 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 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 (CO₂) (Ranasinghe and Thimothias, 2012) [1]. The regulation of the excess of atmospheric CO₂ 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 sequester various passive C pools with a long residence period. Geological, oceanic, chemical and terrestrial transformations are the various CO₂ 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 CO₂ 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 CO₂ 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 tCha−1 yr−1 (Roupsard et al., 2008) [18]. In India, the values were reported as 8 – 32 t CO2 ha−1 yr−1 (equal to 2 – 9 t C ha−1 yr−1) (Anonymous, 2008). Bhagya et al. (2017) [14] 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 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) [14]. 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 CO2 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) [13].

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 12.01115 and 15.9994 respectively. Consequently, 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.

**CO\(_2\) Sequestration by Coconut plantation in Dindigul district**
The carbon sequestered by five, ten, fifteen 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.

**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           |

**Total (green) weight of the coconut tree**
The total green weight of 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.

**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            |

**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.
Discussions

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)\(^{[8, 9]}\). 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. Roupasard 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 forest 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.

References

1. Alexander Clark III, Joseph R Saucier, W Henry McNab. Total-Tree Weight, Stem Weight, and Volume Tables for Hardwood Species in the Southeast. Research Division, Georgia Forestry 1986.
2. Badwal S, Singh R. Carbon sequestration estimates for forestry option under different use scenario in India. Curr. Sci 2002;83(11):1380-1386.
3. Balaji Kannan, Ragunath KP, Kumaraperumal R, Jagadeeswaran R, Krishnan R. Mapping of coconut growing areas in Tamil Nadu, India using remote sensing and GIS. Journal of Applied and Natural Science 2017;9(2):771-773.
4. Bhagya HP, Maheswarappa HP, Surekha, Ravi Bhat. Carbon sequestration potential in coconut-based cropping systems. Indian J Hort 2017;74(1):1-5.
5. CDB. 2018. https://coconutboard.nic.in/Statistics.aspx
6. Corley RV. Potential productivity of tropical perennial crops. Experimental Agriculture 1983;19(3):217-237.
7. Kerr RA. Scientists tell policy makers we’re all warming the world. Science 2007;315:754-757. doi:10.1126/science.315.5813.754 [PubMed] [Google Scholar]
8. Kumar BM. Species richness and aboveground carbon stocks in the homegardens of central Kerala, India. Agriculture, ecosystems & environment 2011;140(3-4):430-440.
9. Kumar BM, Takeuchi K. Agroforestry in the Western Ghats of peninsular India and the satoyama landscapes of Japan: A comparison of two sustainable land use systems. Sustainability Science 2009;4(2):215.
10. Kumar SN, Bai KK, Rajagopal V, Aggarwal PK. Simulating coconut growth, development and yield with the Info Crop-coconut model. Tree physiology 2008;28(7):1049-1058.
11. Lal R. Carbon sequestration. Phil. Trans. R. Soc. B 2008;363:815-830.
12. Lal R, Follett RF, Stewart BA, Kimble JM. Soil carbon sequestration to mitigate climate change and advance food security. Soil Science 2007;172(12):943-956.
13. Miller R, Shennan C. Transition from conventional to low-input agriculture changes soil fertility and biology. Calif. Agric 2002;48:20-26.
14. Navarro MNV, Jourdan C, Sileye T, Bracconner S, Mialet-Serra I, Saint-Andre L et al. Fruit development, not GPP, drives seasonal variation in NPP in a tropical palm plantation. Tree physiology 2008;28(7):1661-1674.
15. Naveen Kumar KS, Maheswarappa HP. Carbon sequestration potential of coconut based cropping systems under integrated nutrient management practices. Journal of Plantation Crops 2019;47(2):107-114.
16. Ranasinghe CS, Silva LRS. Photosynthetic assimilation, carbohydrates in vegetative organs and carbon removal in nut-producing and sap-producing coconut palms. In: Cocos (Vol. 18). Coconut Research Institute of Sri Lanka 2009.
17. Ranasinghe CS, Thimothias KSH. Estimation of carbon sequestration potential in coconut plantations under different agro-ecological regions and land suitability classes. Journal of the National Science Foundation of Sri Lanka 2012, 40(1).
18. Roupasard O, Lamanda N, Jourdan C, Navarro MNV, Mialet-Serra I, Dauzat J et al. Coconut carbon sequestration Part 1/Highlights on carbon cycle in coconut plantations. Part 1 Coconut Research and Development (CORD) 2008;24:1-14.