Original Research Article

Assessing the potential of *Elaeis guineensis* plantations for carbon sequestration and Fresh fruit bunch yield in Coimbatore, Tamil Nadu

ABSTRACT

Elaeis guineensis is one of the potential carbon sequestering perennial crop by biological means. It has helped in the mitigating global warming and climatic fluctuations. The main objective of our study is to evacuate the hidden potential treasure of oil palm in carbon sequestration and vegetable oil yield. In this study we selected Tenera hybrids oil palm plantations in Coimbatore district of Tamil Nadu with standard management practices. It had been selected in the year 2019 and assessed for carbon sequestration potential and Fresh fruit bunch yield by non-destructive carbon stock assessment methods and standard estate practices for harvest. In our study the carbon sequestration is higher in trunks found to be 15.3 t C/ha (tons carbon per hectare) in 5 years and 26.6 t C/ha in 10 years while roots sequestered carbon for about 4.0 t C/ha in 5 years and 6.93 t C/ha in 10 years plantations. The fronds sequesters about 1.39 t C/ha in 5 years and 2.1 t C/ha in 10 years oil palm plantations while the fresh fruit bunch yield in 5 years and 10 years plantations were found to be 7.60 t/ha/year and 12.31 t/ha/year respectively. The present study evidenced that the biomass production and fresh fruit bunch yield in oil palm proportionally increases with the age group.

This study holds that the higher biomass production which increases carbon sequestration and yields in in oil palm helps in altering of the microclimate and to increase the economic benefits of farming communities.

Key words: Oil palm, biomass, carbon sequestration, Fresh fruit bunch yield

1. INTRODUCTION

Oil palm (*Elaeisguineensis*) is one of the most important agricultural crops in the tropics currently the most valuable cash crop of the tropical world (Henderson and Osborne, 2000). An oil palm tree produces 40 kg of oil a year, almost 5720 kg of oil per hectare (Sumathi *et al.,* 2016). Oil palm cultivation initially involves capital expenditure when compared to other annual crops such as paddy for the period of the first four years till yield. The biosphere may soon become a net source rather than a net sink of atmospheric carbon due to changes in climate (Lenton and Huntingford, 2003). Land conversion causes negative environmental impacts such as loss of natural vegetation, reduction in biodiversity, water pollution, and greenhouse gas emissions are critical issues in many oil palm plantations today (Dislich*et al.,* 2017). In Indonesia, the oil palm plantations in 2015 reached up to 11.4 million hectares (Ditjenbun, 2014).

Moreover it sequester carbon in the biomass and trunk which was equivalent to rainforests. Oil palm is one of the higher biomass and oil yielding crop per unit area than other oil seed crops which had been grown widely in Southeast Asia especially in Malaysia and Indonesia. In India oil palm estates extend up to 0.33 million hectares in Andhra Pradesh, Karnataka, Tamil Nadu and Kerala. In Tamil Nadu Oil palm growing districts are Tanjore, Nagapatinam, Cuddalore, Theni, Dindigul and Coimbatore for about 30,900 hectares with the annual production of 16,25,463 Metric tons of Fresh fruit bunches and 2,70,322 Metric tones of Crude Palm Oil (NFSM, 2018). The good management practices in oil palm plantation helps in obtaining potential yield and maximum biomass yield. Maximizing the biomass yield helps in the sequestration of CO_2 and proper management as biomass generation helps in the storage of carbon and other nutrients in the oil palm estates. The management practices such as avoidance of biomass burning, mulching of fronds, returning of EFB to estates, Biochar production, Precise fertilization and co-composting tends to be an effective way in buildup of transitory carbon pools. Terrestrial carbon sequestration is the carbon-storage approach which can be attained by planting perennial crops like oil palm to mitigate climate change and achieve enhanced terrestrial carbon pool. Enhanced biological storage of carbon has the potential to reduce atmospheric CO_2 considerably (Winjum*et al.,* 1992; Mutuo *et al.,* 2005).

Sustainable intensification of oil palm can be achieved by higher net dry matter production and higher partitioning assimilates into fruit bunches (Fairhurst and Griffiths, 2014). The ratio of fruit bunch weight partitioning to the total aboveground dry matter production, the bunch index (BI), is an indicator for fruit production efficiency (Corley *et al.,* 1971a). Comprehensive plantation carbon measurements are imperative to assess the long-term effects of plantation carbon balance on greenhouse gases in the atmosphere. It is currently unprecedented interest to explore the contribution of oil palm as a potential carbon sink. The oil palm stores approximately 90-96% of total annual dry production in the above-ground biomass as trunk, fronds, and bunches (Corley and Tinker, 2003; Kotowska*et al.,* 2015). Maintenance is mainly by pruning of palms and continuous recycling of fronds contribute to annual dry matter production at approximately 10 Mg ha^{-1} yr^{-1} in the Ivory Coast (Hartmann, 1991). The standing stock of palms provides a semi-permanent carbon pool, which, depending on the alternative land uses, would otherwise it enter into the atmosphere. Forest clearing contributes CO_2 to the atmosphere through combustion and decomposition of woody biomass. Over a 25-year typical oil palm plantation lifetime, intact forest conversion is estimated to contribute net emissions of approximately 9–20 t C ha^{-1} yr^{-1} (Carlson *et al.,* 2012). Carbon emissions disconnected from plantations either in time or space and remain unaccounted for by current research. Logging before land clearing for oil palm may contribute 30–60% of emissions from plantation development (Curran *et al.,* 2004; Carlson *et al.,* 2012).

2. MATERIALS AND METHODS

The oil palm plantations of age group between 5 years and 10 years had been selected for the assessment of dry matter production, carbon stock in above and below ground biomass and Fresh fruit bunch yield in Coimbatore district.

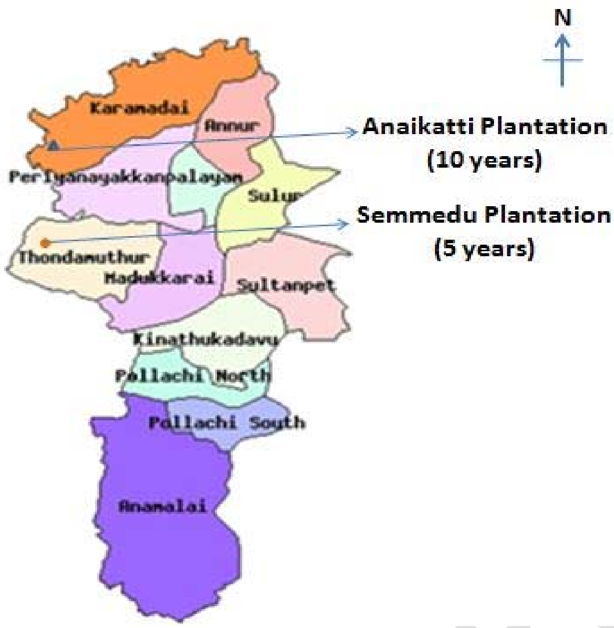

Fig. 1. Description of study site in Coimbatore district

Table 1. Description parameters of the study location in Coimbatore

S.No	Oil Palm Plantation	Age group (Years)	Area (Hectares)	Yielding palms
1	Semmedu	5	10.0	1520
2	Anaikatti	10	3.0	410

2.1 Field measurements and estimating dry matter production

The aboveground dry matter production (fruit bunch, frond, and trunk) and then biomass accumulation in the oil palms depended on key site factors, including soil organic carbon, palm age, and annual rainfall had been estimated.

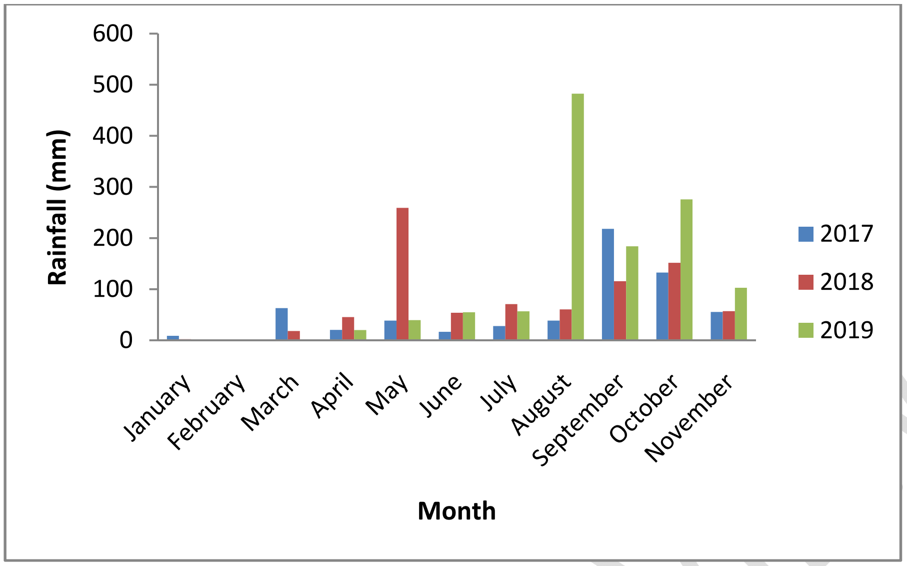

Fig. 2. Monthly rainfall distribution in Coimbatore

The Oil palm trunk girth in 5 years oil palm plantations is measured from 60 cm from base (Sumathi *et al.,* 2016) while it had been measured at 1.3 m height from the base in 10 years by using measuring tape. The height of the tree is measured by Blume-leiss altimeter by non-destructive method. The diameter (d) was calculated by dividing π (3.14) to the actual marked girth of species (Bohre *et al.*, 2012), and above Ground Biomass (AGB) was estimated by multiplying the bio-volume to the green wood density of tree species. Tree bio-volume (TBV) value established by multiplying square of diameter and height of oil palm to factor 0.4.

Tree bio-volume = 0.4 × $(d)^2$ × h
AGB = Wood density × TBV,
Where; d = Diameter (m),
Wood density was used from Global Wood Density database (Zanne *et al.*, 2009).

1. $Above\ ground\ biomass\ production\ (kg/palm) = Volume\ x\ Wood\ density\ (400 - 600\ kg/m^3)$
2. $Above\ ground\ carbon\ sequestered\ (kg/palm) = Above\ ground\ biomass\ (kg/palm)\ x\ 0.50$
3. $Below\ ground\ biomass\ production\ (kg/palm) = Above\ ground\ biomass\ (kg/palm)\ x\ 0.26$
4. $Below\ ground\ carbon\ sequestered\ (kg/palm) = Below\ ground\ biomass\ (kg/palm)\ x\ 0.50$
5. Total Biomass = Above ground biomass production (kg/palm) + Below ground biomass production (kg/palm)

6. Total Carbon Stock (kg/palm) = Above ground Carbon sequestered (kg/palm) + Below ground Carbon sequestered (kg/palm)

7. Total Carbon stock (t C/ha) = Total Carbon Stock (kg per palm) X Planting density (Palms/hectares)

8. CO_2 stock = (t CO_2/ha) = Total Carbon (t C/ha) X 3.67

(Chave *et al.,* 2005; Ravindranath and Ostwald, 2007)

The BGB is generally 26% of its above ground biomass. Carbon stock generally, for any plant species 50% of its biomass is considered as carbon (Pearson *et al.*, 2005),

Carbon stock = Biomass × 0.5 and for estimation of CO_2 (t/ha) sequestered by multiplying Carbon stock (t/ha) with 3.67 as factor. (Bhagya and Mahaeswarappa, 2017)

2.2 Frond carbon estimation

The fronds attached to the trunk are estimated in the oil palm plantation of different age groups and the single frond dry weight was calculated by using digital weighing balance to estimate the standing carbon stock in oil palm trees (Henson, 2006).

Frond carbon stock = N X SFDW X 0.38

Where N is number of fronds, SFDW is Single frond dry weight (kg/frond)

SFDW for 5 years = 0.90 kg/frond

SFDW for 10 years = 1.27kg/frond

2.3 Soil sampling and analysis

The soils were collected in oil palm plantations of Semmedu and Anaikatti of Coimbatore district. The soil samples were air dried and sieved by means 0.2 mm sieve and subjected for analysis of pH, Electrical conductivity, soil organic carbon, total N concentration, extractable P and K as per standard procedure by Jackson (1973).

Table 2. Soil characteristics of Coimbatore oil palm plantation

Parameters	5 years	10 years
pH	7.15	7.10
Electical Conductivity (dS m^{-1})	0.29	0.25
Organic carbon (%)	0.36	0.15
Bulk density (Mg m^{-3})	1.17	1.04
Available N (kg ha^{-1})	260	190
Available P (kg ha^{-1})	24.0	15.0
Available K (kg ha^{-1})	239	195

2.4 Statistical analysis

Data were analyzed by two-way analysis of variance using the SAS statistical program (SAS Institute, Inc. 1999); means were separated by the Duncan test ($P \leq 0.05$).

3. RESULTS

3.1 Above ground dry matter and carbon sequestration

Results revealed that the above ground biomass contributes the major perennial biomass stock in the oil palm plantation. The above ground biomass generation in five years recorded as 219.5 kg per palm with the average of 30.73 t/ha. The above ground biomass in ten years old oil palm plantations recorded to be 380.6 kg per palm with the average of 53.2 t/ha.

The above ground carbon stock in oil palm plantations of five years age group recorded as 15.3 t C/ha while ten years age group recorded the carbon stock of 26.6 t C/ha

Table 3. Dry matter production in oil palm plantations in Coimbatore

S.No	Parameter	Five years*	Ten years*
1	Height (m)	1.12(0.14)	2.69(0.32)
2	Diameter (cm)	95(11)	76.0(5.0)
4	Above ground biomass (kg/palm)	219.5(58.1)	380.6(76.9)
5	Below ground biomass (kg/palm)	57.08(15.12)	98.9(20.0)
6	Above ground Biomass (t /ha)	30.73(8.15)	53.2(10.76)
7	Below ground Biomass (t /ha)	7.99(2.13)	13.85(2.80)
8	Total drymatter production (t/ha)	38.72(10.27)	53.29(10.76)
9	Total drymatter production (t/ha/yr)	7.74(2.13)	5.33(1.08)
10	Frond drymatter production (kg/palm/year)	26.09(3.92)	38.1(4.0)

11	Frond drymatter production (t/ha/year)	3.65(0.55)	5.4(0.6)
12	Fresh fruit bunch yield (kg/palm/year)	54.4(10.3)	87.93(7.90)
13	Fresh fruit bunch yield (t/ha/year)	7.60(1.40)	12.31(1.11)

**The values presented in the table are the average of 15 oil palm trees in each with standard deviation is given in parantheses*

3.2 Carbon sequestration in fronds

The fronds carbon stock for five years plantation was found to be 9.91 kg C/palm/year with the average of 6.95 t C/ha and ten years plantation recorded 14.5 kg C/palm/year with the average of 22.1 t C/ha.

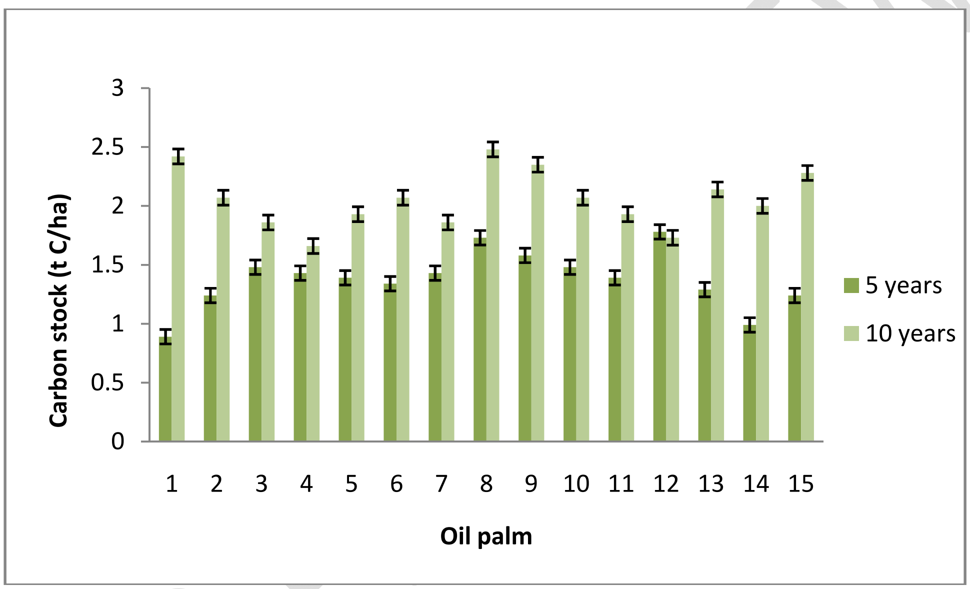

Fig. 2. Variation of fronds carbon stock in Coimbatore regimes

3.3 Below ground biomass and carbon sequestration

The below ground biomass recorded 7.99 t/ha and 13.85 t/ha in five and ten years age groups respectively. The below ground carbon stock in five years age group plantations recorded with the average of 4.0 t C/ha and ten years found to be 6.93 t C/ha.

Table 4. Carbon stock in oil palm plantations in Coimbatore

S.No	Parameter	Five years*	Ten years*
1	Above ground Carbon stock (kg/palm)	109.7(29.08)	190.3(38.4)
2	Above ground Carbon stock (t C/ha)	15.3(4.07)	26.6(5.38)
3	Below ground Carbon stock (kg/palm)	28.5(7.56)	49.44(10.0)
4	Below ground Carbon stock (t C/ha)	4.0(1.06)	6.93(1.40)
5	Total Carbon stock (kg/palm)	138.3(36.6)	239.8(48.4)
6	Total Carbon stock (t C/ha)	19.37(5.13)	33.5(6.78)
7	Total Carbon stock (t C/ha/yr)	1.94(0.51)	3.36(0.68)
8	Frond carbon stock (kg/palm/year)	9.91(1.49)	14.5(1.5)

	Frond carbon stock (t C/ha/year)	1.39(0.21)	2.1(0.2)
8	Carbon di oxide sequestered (t CO_2/ha)	71.07(18.82)	123.2(24.88)
9	Carbon di oxide sequestered per year (t CO_2/ha/yr)	7.11(1.88)	12.32(2.49)

** The values presented in the table are the average of 15 oil palm trees in each with standard deviation is given in parantheses*

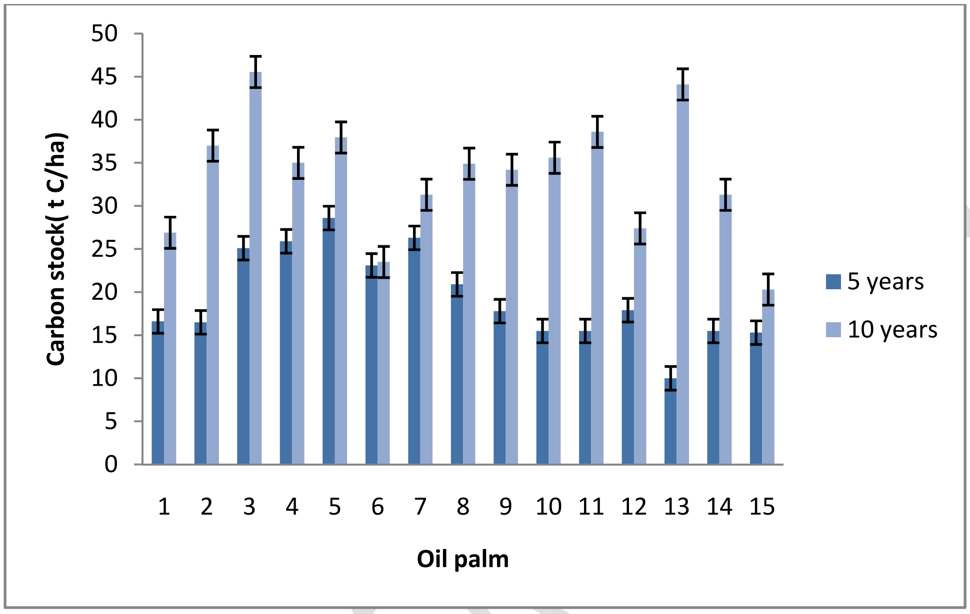

Fig. 3. Total Carbon stock in Coimbatore regimes

3.4 Carbon di oxide sequestration

The carbon di oxide sequestration potential of five years plantations are found to be 71.07 t CO_2/ha with the yearly average of 14.21 t CO_2/ha/yr. The 10 years plantations sequesters about 123.2 t CO_2/ha with the yearly average of 12.32 t CO_2/ha/yr.

3.5 Fresh Fruit Bunch yield

The fresh fruit bunch (FFB) production in five years and ten years oil palm plantations were found to be 54.4 kg/palm/yr and 87.9 kg/palm/yr. The average FFB production in oil palm plantations of five years and ten years age group recorded 7.60 t/ha/yr and 12.31 t/ha/yr.

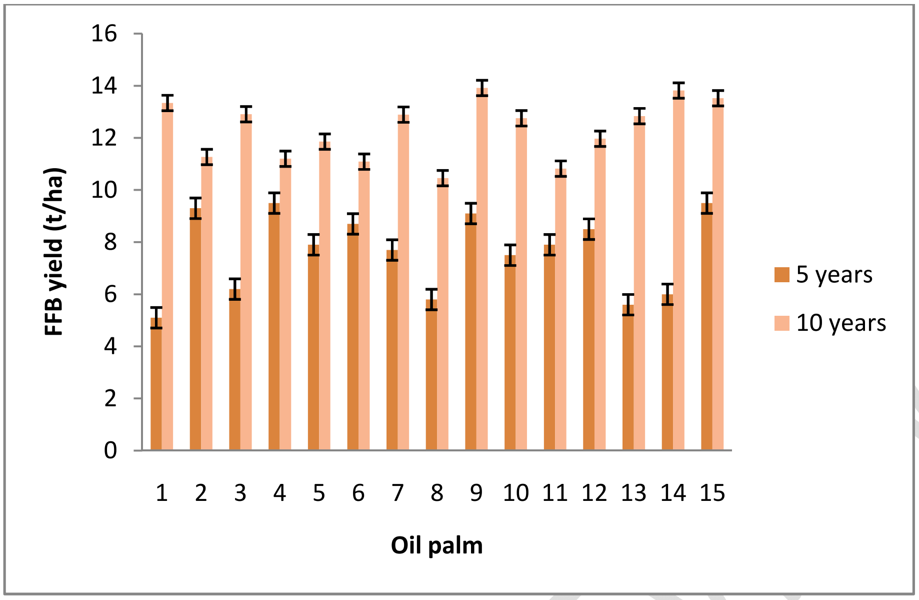

Fig. 4. Fresh fruit bunch yield among various age groups

4. DISCUSSION

Clean Development Mechanism (CDM) provides for the establishment of carbon sinks through afforestation (or) reforestation. It should be point out that, although only forest species are eligible during first phase, tropical tree crop plantations may subsequently be involved. Of these, Oil palm plantations which cover over 12 million hectares on the African, Asian and American continents could prove to be of particular interest. Indeed, their high biomass production and dynamic expansion make them a potentially important carbon sink.

The above ground biomass contributes the major perennial biomass stock in the oil palm plantation. In palm plantations 96% of total annual dry matter is stored in the above ground biomass as trunks, fronds and bunches (Corley and Tinker, 2003). Corley et al., (1971) study revealed that the above ground biomass generation was increased over the time duration of seven years. The improvement of drymatter production was observed in five years old plantation. The similar results were observed in the studies of Suresh and Kumar (2011). The above ground biomass in ten years old oil palm plantations shows highest values. It proves the similarity of Kongsager *et al.,* (2012). The average above ground dry matter production in ten years plantation is found to be similar to studies by Germer and Sauerborn (2008) and also comparable with the studies of Kumar *et al.,* (2017).

The total amount and proportion of C storage varies depending on soil fertility, climate, and land use types (Fahmuddin *et al.,* 2009). The above ground carbon stock in oil palm plantations of five years was found to be similar with the studies of Suresh and Kumar (2011) while ten years age group recorded is still comparable with Syahrinudin (2005) and also with Suresh and Kumar (2011) under irrigated and rainfed conditions. The study clearly shows that the persistant increase in the carbon stock with increase in age group of oil palm due to the increase in biomass of trunks and roots. Results on above ground carbon stock are in line with the study by Suresh *et al.,* (2008) in adult oil palm hybrids. The above ground carbon sequestration in oil palm is comparatively lower than coconut inter cropped with mango and jamun (Bhagya and Mahaeswarappa, 2017) which reveals intercropping sequesters carbon in higher amounts. The carbon stock in oil palm plantations recorded is similar to coffee inter cropped with tree plantations (Negash and Kanninen, 2015). The irrigated oil palm plantation sequesters more carbon which was mainly due to higher biomass production and increased growth rate of the oil palm. It is observed in our study that standing biomass in a ten year old plantation indicated higher biomass under irrigated conditions compared to that of rainfed conditions which was also reported by Suresh and Kumar (2011).

The oil palm fronds arranged in eight spirals and its distribution is due to the specific phyllotaxy with the angle of rotation of frond emission varies from 135°7 to 137°5 (Lamade and Bouillet, 2005). Fronds are numbered from ascending order from crown to the oldest fronds. The fronds carbon stock for five years plantation was found to be similar to results of Kumar *et al.,* (2017) while ten years age group frond carbon stock is comparable with studies of Syahrinudin (2005) and similar to studies of Melling *et al*. (2005) who reported that biomass of the frond base increased substantially from 3-10 and the standing biomass and carbon stock of oil palm the peak in age of 15 and 20 years before declining after 20 years due to lower rates of frond production, loss of frond bases because of abscission in mature palms, loss of palms owing to diseases, less intensive management such as reductions in inputs of fertilizer and pesticides of older, lower-yielding palms (Turner, 1981; Singh, 1992; Hashim and Tey, 2008). Young palms quickly produce more than 20 fronds per year, which are increasingly large, reaching from 5 to 8 metres in length and the light interception of the canopy at 9 years is over 80% has increased photosynthetic activity (Lamade and Bouillet, 2005) as the peak biomass production is achieved in the oil palm plantations between 5-10 years of age.

The oil palm plantations enrich soil organic matter and its higher frond area which leads to increased photosynthetic efficiency. This unique property leads in the regulation of microclimate by increased O_2 production and higher CO_2 absorption from the atmosphere.

The root biomass varies due to soil types and irrigation in oil palm plantations as 89% of carbon losses from atmosphere are mainly because of loss of living biomass of total carbon stored in both vegetation and soil (Houghton, 2005).The below ground biomass stock is one of the important component as roots contribute the major part. Our results on root biomass was found to be similar to results of Suresh and Kumar (2011) in irrigated and rainfed conditions and also comparable with the results of Kumar *et al.,* (2017). The root biomass production in ten years plantation is still comparable with the studies of Sommer *et al*. (2000) in 9 years old oil palm plantation in eastern Amazon. Root biomass is more difficult to estimate and its measurement requires destructive sampling (Fahmuddin *et al.,* 2009). Carbon storage in the biomass elaborates each year primarily with the age and secondarily on agro-ecological conditions. Loss of standing biomass may be offset by long-term carbon storage, either as harvested material or carbon sequestered in soil organic matter. The root biomass is representative more widely of oil palm plantations on mineral soil and also highlights the substantial increase in root biomass towards the end of the commercial lifespan of such plantations was reported by Syahrinudin (2005)

The below ground carbon stock in five years age group plantations was comparable with reports of Syahrinudin (2005) and ten years age group was found to be lower to studies of Khoon *et al.,* (2019) in 21 years plantation. Roots contributed 14.4-34.2%, and together with the trunk base produced 22.4-38.0% of the total crop biomass.

The carbon di oxide sequestration potential of five years plantations found to be similar with the studies on coconut with intercropping by Kumar and Maheswarappa (2019). The carbon di oxide sequestration of ten years plantations was found to be two fold decrease in carbon di oxide sequestration reported by Bhagya *et al.,* (2017) in coconut mono-cropping system. The atmospheric humidity also strongly influences oilpalm photosynthetic capacity. Low air humidity restricts stomatal opening and CO_2 uptake (Smith, 1989).

The fresh fruit bunches (FFB) is the economic part of the oil palm which contains mesocarp by which crude palm oil is extracted and kernel is used in the extraction of palm kernel oil. The average FFB production in oil palm plantations of five years and ten years age group were comparable with the studies of Sumathi *et al.,* (2016) in cauvery delta region. The higher yield is attributed mainly by higher female sex ratio and also comparable with studies of Tao *et al.,* (2017). Under favorable growing conditions, an inflorescence is initiated in the axil of each leaf of the palm. The rate of leaf production varies with age and on an average three leaves are produced per month in young palms and two per month in the case of older palms (Verheye, 2010).The inflorescence initiation to maturity period ranges up to 36 months. The tropical humid climates with regular water supply and rainfall leads to sustainable fruit production in oil palm (Sumathi *et al.,* 2016). Typically, a mature palm will alternate between male and female inflorescence production during its lifetime. In regions with high and regular rainfall, oil palm sex ratios tend to vary little throughout the year, in contrast to areas experiencing a marked dry season, where the sex ratio undergoes extensive fluctuations. The oil palm sex determination is strongly influenced by climatic factors, with male inflorescence production being promoted by water deficit (Adam *et al.*, 2005). Carbon allocation to heterotrophic organ such as bunches was around 17% of the assimilates produced. (Lamade and Bouillet, 2005)

Water supply is the main yield-limiting factor in oil palm (Kallarackal *et al.*, 2004). The oil palm industry is focusing on yields mainly in terms of FFBs, relegating the critical parameters of bunch oil extraction rate and kernel extraction rate (Ng *et al.*, 1998).The increasing of average bunch weight in irrigated palms had contributed on total FFB that was influenced by good soil moisture which enables water storage was made in bunch development. Respiration and transpiration activities in oil palm will go on favourably with continuous photosynthesis process which involves the production of CH_2O also helped in bunch development.

5. CONCLUSION

Oil palm being a perennial crop has higher production of the vegetable oil than other oil yielding crops. The carbon sequestration is equivalent to that of rainforests. The higher carbon stocks in oil palm is mainly due to higher biomass production and storage in trunks, fronds, roots and fruit bunches which helps in partitioning the carbon stock in oil palm. The carbon sequestration in the oil palm paves the way for the mitigation of the climate change by means of biological carbon sequestration and higher vegetable oil production to increase the economic and environment benefit for farming communities and people.

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