Original Research Article

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

ABSTRACT

Elaeisguineensis is one of the potential carbon sequestering perennial crop by biological means has helped in mitigating global warming and climatic fluctuations. In our study we selected Tenera hybrids plantation in Coimbatore district of Tamil Nadu with standard management practices had been selected in the year 2019 and assessed for carbon sequestration potential and Fresh fruit bunch yield. 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.

The present study proves that the biomass production and yields in in oil palm helps in altering of the microclimate and to increase the economic benefits of farming communities.

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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. Lenton and Huntingford (2003) reported that the biosphere may soon become a net source rather than a net sink of atmospheric carbon due to changes in climate. 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 oilseed 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

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tones of Crude Palm Oil (NFSM, 2018). The good management practices in oil palm plantation helps in obtaining potential yield and maximum biomass yield. The maximizing the biomass yield helps in the sequestration of CO_2 and proper management after 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 CO2 considerably (Winjum*et al.,* 1992; Mutuo*et al.,* 2005).

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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 Mgha^{-1} yr^{-1} in the Ivory Coast (Hartmann, 1991). The standing stock of palms provides asemi-permanent carbon pool, which, depending on the alternative land uses, would otherwise it enter into theatmosphere. 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).

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2. MATERIALS AND METHODS

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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.

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

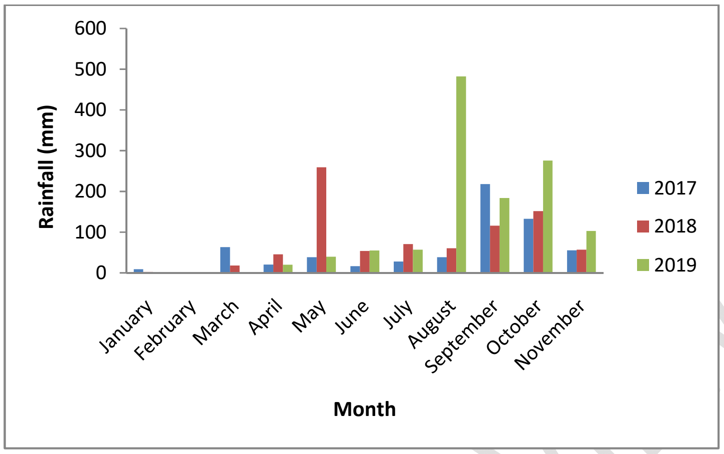

Fig. 1. Monthly rainfall distribution in Coimbatore

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.

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

1. $Above\ ground\ biomass\ production\ (kg/palm) = Volumex\ Wood\ density\ (400 - 600\ kg/m^3)$
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. (Bhagyaand 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

3. RESULTS AND DISCUSSION

3.1 Above ground dry matter and carbon sequestration

The above ground biomass contributes the major perennial biomass stock in the oil palm plantation. In palm plantation 96% of total annual dry matter production is stored in the aboveground biomass as trunks, fronds and bunches) (Corley and Tinker, 2003). The above ground biomass generation in five years recorded as 219.5 kg per palm which was found to be similar to 7 years plantation in studies of Corley *et al.,* (1971). The five years plantation produces drymatter of 30.73 Mg ha^{-1} which was comparable with the studies of Suresh and Kumar (2011). The above ground biomass in ten years old oil palm plantations recorded to be 380.6 kg per palm which was comparable with the results of Kongsager *et al.,* (2012). The average above ground drymatter production in ten years plantation recorded 53.2 tons per hectare which is found to be similar to studies by Germer and Sauerborn (2008) and also comparable with the studies of Kumar *et al.,* (2017).

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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 age group recorded as 15.3 Mg C ha^{-1} which was found to be similar with the studies of Suresh and Kumar (2011) while ten years age group recorded the carbon stock of 26.6 Mg C ha^{-1} which 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. Our results on above ground carbon stock are comparable 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 which was found by Bhagya and Mahaeswarappa (2017) which reveals intercropping sequesters carbon

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Comment [a20]: Remove this and then bracket the authors and the date as (Bhagya and Mahaeswarappa , 2017) in higher amounts. The carbon stock in oil palm plantations recorded to be similar to coffee inter cropped with tree plantations had been reported by Negash and Kanninen (2015). The irrigated oil palm plantations 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).

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Table 3. Drymatter production in oil palm plantations in Coimbatore

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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 paranthesis*

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3.2 Carbon sequestration in fronds

The oil palm tree produces 20-24 fronds per treeannually are pruned during harvesting of fresh fruit bunches. The fronds carbon stock for five years plantation was found to be 6.95 t C/ha which was similar to results of Kumar *et al.,* (2017) and 22.1 t C/ha for ten years which was still comparable with studies of Syahrinudin (2005). Our study is comparable with the studies like Melling*et al*. (2005) 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).

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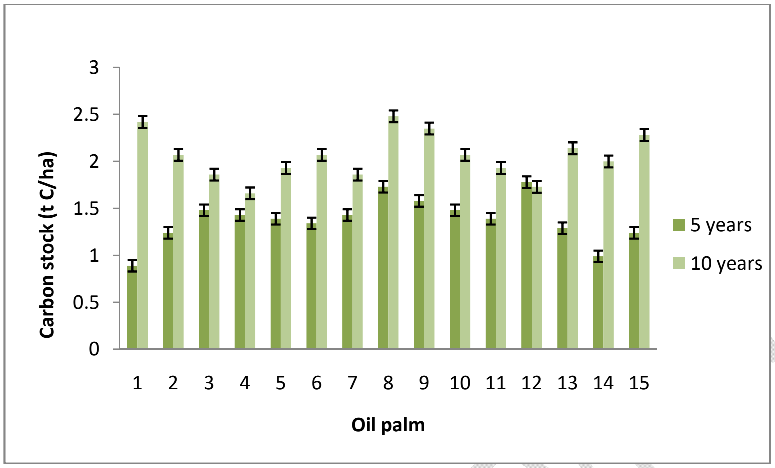

Fig. 2. Variation of fronds carbon stock in Coimbatore regimes

The oil palms plantation helps to 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.

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3.3 Below ground biomass and carbon sequestration

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. The below ground biomass recorded 7.99 tons per hectare and 13.85 tons per hectare in five and ten years age groups respectively. 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)

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The below ground carbon stock in five years age group plantations recorded with the average of 4.0 t C/ha which was comparable with reports of Syahrinudin (2005) and ten years found to be 6.93 t C/ha which 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.

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 paranthesis*

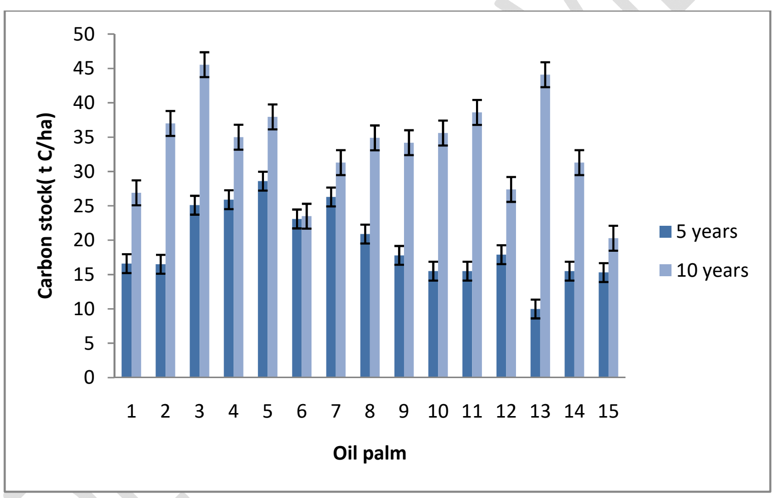

Fig. 3. Total Carbon stock in Coimbatore regimes

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^{-1} which found significantly with the studies on coconut with intercropping by Kumar and Maheswarappa (2019). The 10 years plantations sequesters about 123.2 t CO_2 ha^{-1} which 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).

3.5 Fresh Fruit Bunch yield

The fresh fruit bunches being the economic part of the oil palm which contains mesocarp by which crude palm oil is being extracted and kernel is used in the extraction of palm kernel oil. The fresh fruit bunch production in five years and ten years oil palm plantations were found to be 54.4 kg per palm per year and 87.9 kg per palm per year. The average FFB production in oil palm plantations of five years and fifteen years age group recorded 7.60 tons per hectare per year and 12.31 tons per hectare per year which were comparable with the studies of Sumathi*et al.,* (2016) in cauvery delta region as the higher

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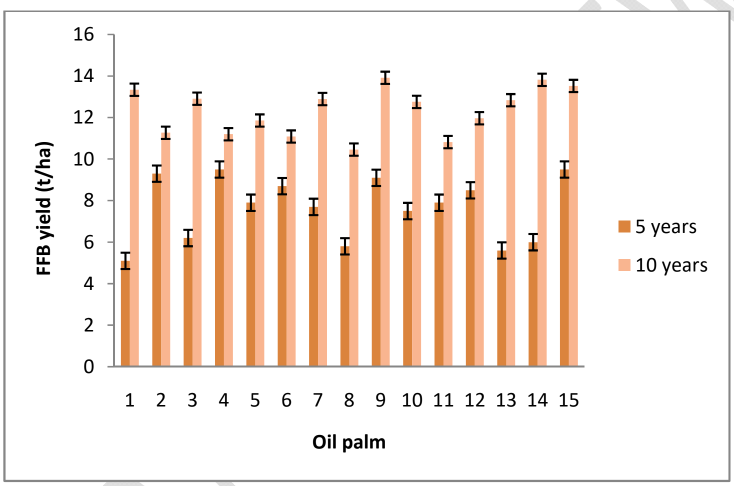

Fig. 4. Fresh fruit bunch yield among various age groups

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 favorably with continous photosynthesis process which involves the production of CH_2O also helped in bunch development.

4. 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 cabon stocks in oil palm is mainly due to higher biomass production and storage in trunks, fronds, roots and fruit bunches which helps in partitioning in 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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