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Soil Carbon Sequestration in Different Ages of Oil Palm Plantations

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Abstract: Organic carbon content in soil are varies in different palm ages. Increasing the carbon (C) sequestration potential of the soil is one of the ways to address the increasing build-up of greenhouse gases especially carbon dioxide (CO_2). Thus, the aim of this study was to determine the soil C sequestration under oil palm plantations at four different age groups in New Labu Estate, Negeri Sembilan, Malaysia. Eighty soil samples were collected at the studied area based on different palm ages (0-5, 6-10, 11-15 and 16-20 years). The soil samples were collected for bulk density and organic carbon determinations. Soil organic carbon content was determined by using Walkley and Black method whereas bulk density using waxing method. Carbon stocks were calculated using measured carbon content and the corresponding soil bulk densities. The organic carbon in the soil increased along the age groups from 1.70 to 1.89% with the average of 1.82±0.09%. The C stocks changes with time of all age groups were declined more than 50% over the year from 0.68 tan/ha/year in the first 10 years to 0.15 tan/ha/year in the last 5 years. The annual C increment decreased gradually and the rate of decline from the first 10 years to the last 5 years was 2.65 tan/ha.

Key words: Carbon Sequestration · Soil Organic Carbon · Carbon Dioxide · Different Palm Ages

INTRODUCTION

Oil palm (*Elaeis guineensis*) was first introduced to Malaysia as an ornamental plant in 1870. Since 1960, planted area had increased at a rapid pace. In 1985, 1.5 million hectares were planted with palm tree and it had increased to 4.3 million hectares in 2007 [1]. Oil palm plantation is the most valuable oil crops in Malaysia. It is a major source of oils and fats for human food, animal feeds and for manufacture of many domestic products such as cosmetics, soap and detergents.

The establishment of oil palm has led to the conversion of natural vegetation into oil palm plantations. The conversion of some rainforests and use of abandoned logged-off forests into oil palm plantations might have significantly contributed to losses in C from both soil and vegetation to atmosphere. According to Chibsa & Ta'a [2], increasing intensity of tillage and conversion of natural ecosystem to agricultural land has led to the decreasing of soil organic matter levels due to reduced inputs of organic carbon and reduced physical protection of soil organic carbon (SOC) content.

A study by Haron *et al*. [3] has measured changes in C content from destruction of the forest ecosystem to its replacement by an oil palm plantation. The researchers observed that there was a slight drop in soil C in the first 4 years as the young oil palm develop, then the rates seems to stabilize from 9 years old onwards. Soil C plays an important role in maintaining soil productivity that makes land management systems sustainable, resilient and able to resist degradation [4]. Lal [5] stated that soil C stock can be increased through agricultural management including site preparation, fire management, afforestation, species selection, use of fertilizers and soil amendments.

Clay [6] reported that the negative impacts of oil palm on the environment include deforestation and habitat loss of critically endangered species and a significant increase

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in greenhouse gas emissions. Many rainforests in Malaysia lie on top of peat bogs that store huge amount of carbon, which are released when the forests are logged-off and the bogs are drained to make way for plantation [7].

An oil palm plantation with its perennial green cover and closed canopy displays the main features of a tropical rainforest. Oil palm plantations are becoming the center of environmental controversies with regard to deforestation in the tropics. It has led to the decreasing in the C pool to a magnitude of more than 50% lower than the original forest stock [8]. Some studies showed that oil palm plantation can act as carbon sink, converting carbon dioxide into oxygen [9]. The roles of oil palm plantation as a carbon sink or source are still in global debate. Protecting and enhancing SOC stocks is a global challenge before environmental scientists and researchers for the next decade and beyond [10]. The objectives of this carried out study was to assess the dynamic changes of soil carbon sequestration under oil palm plantation of different age groups.

MATERIALS AND METHODS

The sites chosen for the study are owned by Sime Darby Plantations. The sites are located in Labu, Negeri Sembilan, Malaysia at 2° 42' 38.55" N to 2° 46' 13.5264" N and 101° 47' 44.72" E to 101° 50' 15.6438" E. The oil palm plantations were categorized into four age groups (0-5, 6-10, 11-15 and 16-20 years). A number of 80 soil samples were collected at 30 cm depth from the study area based on different palm age by using Dutch Auger. Dutch auger is a soil sampler which has a unique open design that allows for easier removal of hard or wet soil. Hand forged from high-carbon steel and honed to a fine cutting edge enable the tool to 'cut' through high fibrous and heavily rooted soil and excellent for use in forests, vineyards and orchards. In this study, it was used to drill the soil in the 30 m depth at the sampling point. The collected soil samples were air dried, crushed and sieved through 2 mm to get rid of stones, roots, twigs and other unwanted materials.

Soil organic carbon content was determined by using Walkley and Black method [11] whereas bulk density using waxing method [12]. Carbon stocks were calculated using measured carbon content and the corresponding soil bulk densities. Carbon changes (dynamics) were calculated by subtracting the current C stock of an age group from the previous age group and the difference recorded as what has been added to the soil. C increment per year was done by subtracting the value under dynamics for a particular age group from that of the preceding per year and dividing the resultant by 5 since the age groupings were done using 5 years interval. Microsoft Office EXCEL was used for computer analysis.

RESULTS AND DISCUSSION

The soil organic C content, C stock and bulk density were presented in Table 1. The average of bulk density across all the age groups was 1.03±0.00 g cm^{-3}. The bulk density were remained the same for all of the age group and there were no significant differences observed ($p<0.05$). There were a slight increased of organic C from 5 to 20 years of plantation age which was between 0.02 - 0.11% and had no significant different ($p<0.05$). The average of organic C in all of the plantation age groups was 1.82±0.09%. The C stock shared the similar increment pattern as the C content. The soil C levels were increasing with the age of the oil palm from 52.35 tan/ha to 58.33 tan/ha.

Changes in C stocks were displayed in Table 2. The C stock changes with the time were decreased for every 5 years from 3.42 tan/ha to 0.77 tan/ha. It was proved by the annual increment trend of C stock was diminution from 0.68 tan/ha/year to 0.15 tan/ha/year. The carbon dynamics in soils showed a sharp declined in C.

Bulk density values were influenced by organic matter (OM) content. OM under oil palm plantation plays a vital function in improving the physical properties of

Table 1: Soil organic C content, C stock and bulk density

	Age Groups (Years)				
Properties	0-5	06-10	11-15	16-20	Average
Organic C (%)	1.70	1.81	1.87	1.89	1.82±0.09
C Stock (tan ha^{-1})	52.35	55.77	57.56	58.33	56.00±2.66
Bulk Density (g cm^{-3})	1.03	1.03	1.03	1.03	1.03±0.00

Table 2: Changes in C stocks in oil palm soils with age of plantation

	Age Groups (Years)			
Properties	0-5	06-10	11-15	16-20
C Stock (tan ha^{-1}) Current	52.35	55.77	57.56	58.33
C Stock (tan ha^{-1})				
Changes with time	**	3.42	1.79	0.77
Mean Increments/year		0.68	0.36	0.15

** Represents initial year from which additions took place later.

soil and by that contributing to the soil structural stability [13]. The organic C contents are varied due to the amount, location, quality and action of temperature and moisture of the soil [14]. The slightly increasing in organic C might be due to the increasing of soil organic matter. The addition of organic material sources such as empty fruit bunch and palm fronds as the palm trees grow will be resulted in the rising of organic C [15]. The higher organic C along the year proved from field observations that the soil had received numerous numbers of pruned materials particularly under older plantations. According to Yahya *et al*. [16], the reduction of machinery usage during the harvesting and cultural managements could reduce the disruption of organic matter decomposition.

The different plant species present as undergrowth from time to time after the years of planting could also be responsible for adding to C input (when cut, left on soil surface and decompose) and at the same time C removal when the oil palm trees absorb part of dissolved organic C from the soil [17]. In addition, the effect of erosion might be causes the losses of organic C on one side and at the same time cause the additions of organic C at another side. The potential of the soil in holding more C stocks might be limited due to intrinsic limitations imposed by climatic factors [18, 19].

Average increment per year were decreased gradually and the rate of decline from the first 10 years to the last 5 years was 2.65 tan/ha. If this rate of loss should continue then the soil C storage in the next 10 years will be decreased and oil palm production would be affected.

CONCLUSION

The presented results above showed that the organic C in the study area was increased for all of the age groups. The C stock sequestration followed a comparable trend as organic C content. The system of adding pruned materials to soil as residue seems to improve the storage of carbon. The annual C stock dynamics in the last 5 years were drastically dropped compared to the first ten years.

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