Application of Empty Fruit Bunches of Oil Palm and *Indigofera zollingeriana* for Conservation of Oil Palm Plantation

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ABSTRACT

Oil palm empty fruit bunches are materials used as organic fertilizers that can be applied to oil palm plantations, thereby reducing the use of inorganic fertilizers. *Indigofera zollingeriana* is an appropriate alternative as an interplant because of its high branch and leaf development. Functions as a ground cover and a supplier of carbon stocks naturally plays a role in water and soil conservation. This study aims to determine the effect of oil palm empty fruit bunches and I. *zollingeriana* on land improvement to support oil palm growth and production. Variables observed included changes in soil water content, soil microorganism activity, and carbon stock. The results showed that the soil planted with I. *zollingeriana* and given the empty fruit bunches of oil palm had a higher soil moisture content. The highest soil carbon stock, oil palm carbon stock, and vegetation carbon stock were 81.6 t ha^{-1}, 36.60 t ha^{-1}, and 1.89 t ha^{-1}, respectively. The population and activity of microorganisms varies. The highest total microorganisms were treated with I. *zollingeriana* and oil palm EFB 105 (10^{5}CFU g^{-1}), while the lowest was 60 (10^{5}CFU g^{-1}). Planting I. *zollingeriana* and providing oil palm empty fruit bunches increased groundwater reserves by 36.71%.

Keywords: Carbon stock, Indigofera zollingeriana, Microorganisms

ABSTRAK

Tandan kosong kelapa sawit merupakan bahan yang digunakan sebagai pupuk organik yang dapat diaplikasikan pada perkebunan kelapa sawit, sehingga dapat mengurangi penggunaan pupuk anorganik. Indigofera zollingeriana merupakan alternatif yang tepat sebagai tanaman interplant karena pertumbuhan cabang dan daunnya yang tinggi. Fungsinya sebagai penutup tanah dan pemasok stok karbon secara alami berperan dalam konservasi air dan tanah. Penelitian ini bertujuan untuk mengetahui pengaruh tandan kosong kelapa sawit dan I. zollingeriana terhadap perbaikan lahan untuk mendukung pertumbuhan dan produksi kelapa sawit. Variabel yang diamati meliputi perubahan kadar air tanah, aktivitas mikroorganisme tanah, dan stok karbon. Hasil penelitian menunjukkan bahwa tanah yang ditanami I. zollingeriana dan diberi tandan kosong kelapa sawit memiliki kadar air tanah yang lebih tinggi. Stok karbon tanah, stok karbon kelapa sawit, dan stok karbon vegetasi tertinggi berturut-turut adalah 81,6 t ha^{-1}, 36,60 t ha^{-1}, dan 1,89 t ha^{-1}. Populasi dan aktivitas mikroorganisme bervariasi. Total mikroorganisme tertinggi pada perlakuan I. zollingeriana dan TKKS kelapa sawit 105 (10^{5}CFU g^{-1}), sedangkan terendah 60 (10^{5}CFU g^{-1}). Penanaman I. zollingeriana dan penyediaan tandan kosong kelapa sawit meningkatkan cadangan air tanah sebesar 36,71%.

Kata kunci: *Stok karbon, Indigofera zollingeriana, Mikroorganisme*

INTRODUCTION

Oil palm plant grows, develops, and produces optimally if the availability of groundwater is sufficient all years, with a rainfall of 2000-2.500 mm in the first year and a dry season of less than one month or no dry season (Henson et al., 2005; Kallarackal et al., 2004; Umana & Chinchille, 1991). The oil palm industry has grown exponentially over the past years. This case causes an increase in the number of waste products from the oil palm industry, especially empty fruit bunch (EFB) of palm oil. EFB is produced in large quantities in the local area. Recycling EFB through conversion into a usable product is the most appropriate way to reduce raw waste materials. There are several

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potential solutions for EFB to be used as compost material (Danmanhuri, 1998), and EFB can also be used as ground cover on the plantation (Mohammad et al., 2012), becoming an effective solution and inexpensive waste utilization.

Agricultural land conservation aims to create minimum soil mechanical disturbance, make nurseries without tillage, use organic ground cover, and diversify plants. Benefit potential includes higher productivity and income, climate change adaptation and susceptibility to erratic rainfall distribution, and reduction of greenhouse gas emissions (Kassam et al., 2012). Soil and water conservation through the agroecosystem approach can increase the benefit of farming and improve food security and land productivity (Robert, 2001). Other efforts include simultaneously applying three principles of soil and water conservation, namely minimum tillage, use of permanent ground cover, and plant rotation. A recent study has shown that minimum tillage combined with the cover plant has the potential to offer better soil conservation in cropping systems in tropical mountain areas, as well as to facilitate stability and increase harvest production several times, without the main weaknesses found with the hedge contour (Hobbs, 2007; Shafi et al., 2007). Pansak et al., (2008) found that planting ground cover and legumes showed a positive response and helped control lost nutrients in corn on the moderate slope in northeast Thailand, making this type of soil conservation a proper alternative to tropical mountain areas.

Indigofera zollingeriana is a type of shrub-shaped legume plant that has many leaves. This plant has an important benefit in developing sustainable oil palm plantations because the leaves can be used as a ground cover plant, increasing the source of organic material and carbon stock (Hassen et al., 2006). *Indigofera zollingeriana* can adapt highly to diverse environments and has a variety of important morphological and agronomic characteristics to be used as a forage and ground cover plant (Hassen et al., 2006). *Indigofera zollingeriana* can be used as a ground cover plant to prevent the transport of organic matter and nutrient loss on the soil's surface (Hassen et al., 2006). Utilization of oil palm empty bunches of waste applies the traditional composting method for several months or years to achieve complete decomposition. The high C: N ratio and polymer, such as cellulose and lignin in EFB, act as a natural inhibitor of natural biodegradation (Gaind & Nain, 2007). Using organic waste as organic fertilizer can increase plant productivity, improve soil health, and reduce the waste problem (Gaind & Nain, 2007). This study aimed to determine the effects of *Indigofera zollingeriana* and EFB as well as other treatments on improving the growing environment to support the growth and production of oil palm.

MATERIALS AND METHODS

The materials used were 5-month-*Indigofera zollingeriana* seedlings, 5-year-old-oil palm plants with a shade range of 33-50%, and EFB. Meanwhile, the equipment used included analytical and digital scales (Shimadzu ATX224), digital camera (Sony), Oven (Memmer), multimeter (Tofuda DT830B), and binocular microscope **(Olympus)**. The research was carried out for 12 months from November 2019 to October 2020, at the Oil Palm Plantation at an elevation of 115 m asl. Analysis of soil, fertilizer, and plant net was carried out at the Soil Fertility Laboratory of IPB Bogor.

Treatments Application

The research was arranged in a single factor Randomized Complete Block Design, consisting of five treatments, namely experimental plot overgrown with natural vegetation, experimental plot without natural vegetation, experiment plot

Figure 1. EFB Application

Figure 2. 3-month-*Indigofera zollingeriana* plants

planted with *Indigofera zollingeriana*, experiment plot treated with empty fruit bunch (EFB) of palms oil, and experimental plot planted with *Indigofera zollingeriana* and treated with EFB. Each treatment was replicated three times, resulting in 15 experimental units. The data collected were analyzed statistically using ANOVA at a 5% significance level (Steel and Torrie, 1993)

The first step was preparing the experimental field design by making a test plot with a size of 45 m x 8 m. The number of oil palm plant samples observed during the study was three plants for each treatment plot, so there were 45 plant samples. The image of the application of empty palm bunches can be seen in Figure 1, and the performance of 3-month- *Indigofera zollingeriana* plants can be seen in Figure 2.

The variables observed in this study were groundwater reserves, activities of soil microorganisms, and carbon stocks.

Soil moisture content

Measurement of soil moisture content was carried out in an experimental plot using the planted sensor in the soil at a depth of 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, and 60 cm (Asbur & Ariyanti, 2017), which was then measured by a multimeter (Tofuda DT830B). Measurement was made only once at a determined time in the morning. The measured value was the soil conductivity value. The value of soil conductivity has a certain correlation function with soil moisture content. The correlation function was obtained from calibration (Asbur & Ariyanti, 2017).

The activity of soil microorganisms

The activities of soil microorganisms observed include the total number of microorganisms and soil microorganisms' respiration. The content of organic C, total N, available P, and total K was determined using the Walkley and Black method (Kjeldahl), Bray method and 25% HCL extract by spectrophotometer, and 25% HCL compound with f flame-photometer, respectively. The soil sample was taken from each plot at 0-20 cm depth (Asbur & Ariyanti, 2017)

Carbon stock

Soil carbon stock was calculated by the formula of **C-k n = C-conc × BD × d × CFst.** Oil palm carbon stock was calculated by formula of AGB = 0.0976^{h}total + 0.0706. Meanwhile, the carbon stock of natural vegetation was measured by making a sample plot (1 m x 1 m), and all vegetation was taken and then dried at a temperature of 80°C to constant weight. The dry weight of the biomass obtained was converted to kg ha^{-1} to determine biomass weight in the experimental plot. Then, the

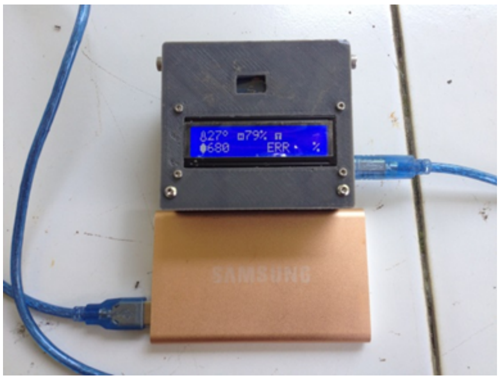

Figure 3. Multi Meter

Figure 4. Measuring SMC

carbon stock was calculated by the formula of C = biomass (kg ha^{-1}) x vegetation C content. (Hairiah et al., 2011)

Data analysis

The formula for calculating soil moisture content is

$$w = \frac{W2\ W3}{W3\text{-}W1} x 100\% \quad (1)$$

Soil biological activity is calculated by the formula

$$r = \frac{(a-b)xtx120}{n} \quad (2)$$

while the formula for calculating carbon stock in oil palm plantations is Y = 0,002382 .D2,3385 . H0,9411. Statistical analysis design, using minitab Software version 19 (Sihombing & Arsani, 2022).

RESULTS AND DISCUSSION

The study area is located at an altitude of ± 115 m above sea level, with a relatively flat topography. Climatic conditions show rainfall ranging from 100-489 mm with an average temperature of 26-30°C. Humidity ranges from 78% to 80%, indicating that external environmental conditions require action to improve the growing environment by planting *Indigofera zollingeriana* and giving empty bunches of oil palm. *Indigofera zollingeriana* can be used as a ground cover plant and water storage (Hassen et al., 2006). It also functions as green fertilizer that can have a symbiotic relationship with *Rhizobium* sp. so that it can fix N from the air. Besides, *Indigofera zollingeriana* plants are plants adapted to the shade intensity of 40% (Saijo et al., 2018), so they are planted under oil palm stand 3-5 years after planting. Goh & Hardter (2003) state that the provision of nitrogen can increase leaf area, number of leaves, and average assimilation level in oil palm plants. In this study, the availability of water reserves in the soil was influenced by the planting of *Indigofera zollingeriana* and the treatment of empty oil palm bunches. Figure 3 shows a multimeter tool used to measure soil moisture content, while the documentation when measuring soil moisture content is shown in Figure 4.

The lowest soil moisture content was observed in July (28.78%), while in November, the soil moisture content was 60%. However, the deficit of soil moisture content tended to decrease by treating EFB and *Indigofera zollingeriana* as ground cover. At almost all depths (0-60 cm), the effects of *Indigofera zollingeriana* could reduce the deficit of soil moisture content. Water tends to be available below the soil with *Indigofera zollingeriana* root system (Hassen et al., 2006). In this case, the role of *Indigofera zollingeriana* plant was more significant, especially in dry months, where soil moisture content in the plot planted with *Indigofera zollingeriana*

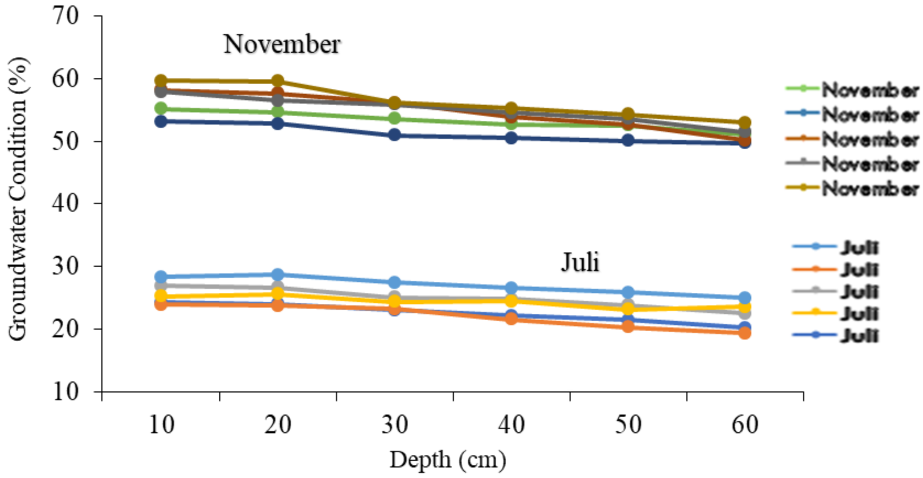

Figure 5. Effects of treatments on the soil moisture content in an extremely dry month (July) and wet month (November)

tended to be better than in the plot without plants. The extreme conditions of soil moisture content in the dry month (July) and wet month (November) can be shown in Figure 5.

To retain soil moisture content in the dry season, it is recommended to provide shade plants (above 80%) and cover the soil with litter (100%) (Saijo et al., 2018). The ground cover with the application of *Asystasia gangetica* can significantly increase the soil moisture content to 33%-66% (Saijo et al., 2018). From October-February, there was an increase in the average daily soil moisture content due to the high rainfall that occurred during these months. The effects of *Indigofera zollingeriana* + EFB started to appear in January, especially at the soil depth of 10-20 cm. The average daily soil moisture content increased in the plot planted with *Indigofera zollingeriana* plants as ground cover. In the rainy season, *Indigofera zollingeriana* + EFB in retaining soil moisture was effective only at a soil depth of 30 cm. This result is due to the effective growth and spread of *Indigofera zollingeriana* roots at a soil depth of 30 cm, thereby allowing rainwater to be retained in the zone.

Meanwhile, in November, these plants could retain higher soil moisture levels, up to a soil depth of 60 cm, because there was water surplus at depths of 10 cm to 60 cm. Water that enters the soil mostly flows as air percolation so that it is not trapped in the soil profile. The roots of *Indigofera zollingeriana* plants can reduce the occurrence of greater percolation, which is indicated by a lower air deficit at a soil depth of 20 cm.

The activity and population of soil microorganisms varied between treatments. The highest respiration was in the experimental plot planted with *Indigofera zollingeriana* + EFB (72.00 CO_2-C 100^{-1} g soil of day^{-1}), and the lowest was in control (61.71 CO_2-C 100^{-1} g soil of day^{-1}). Meanwhile, the highest total microorganism was also found in the plot planted with *Indigofera zollingeriana* + EFB, which was 105 (10^5 CFU g^{-1}), while the lowest total microorganisms were in the control plot (60 (10^5 CFU g^{-1})). The high level of respiration and the large number of total microorganisms on the plots treated with *Indigofera zollingeriana* and empty bunches of palms are thought to be due to the presence of litter sourced from *Indigofera zollingeriana* leaves and empty bunches of palms that contain a lot of organic matter, thereby automatically increas-

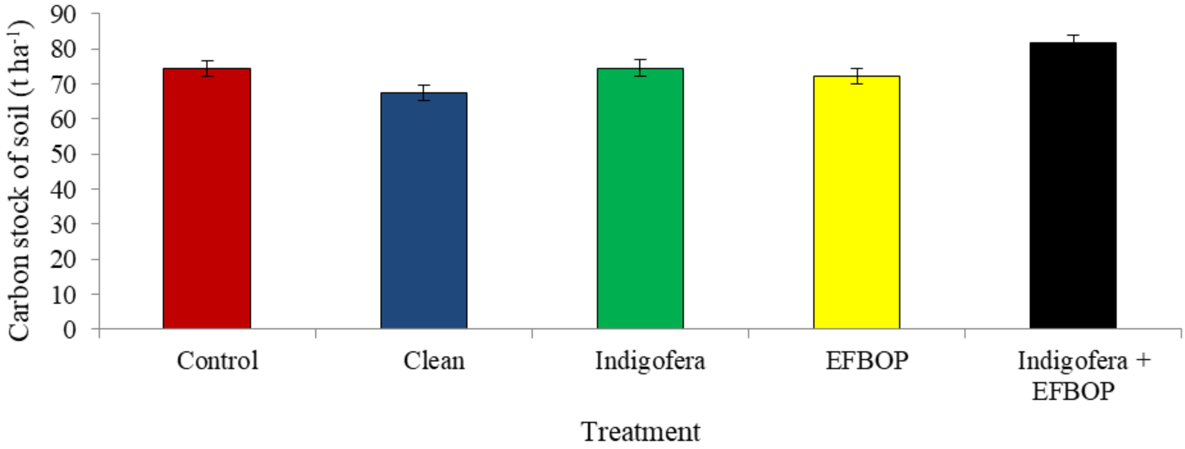

Figure 6. Effects of the treatments on carbon stocks of soil (t ha^{-1})

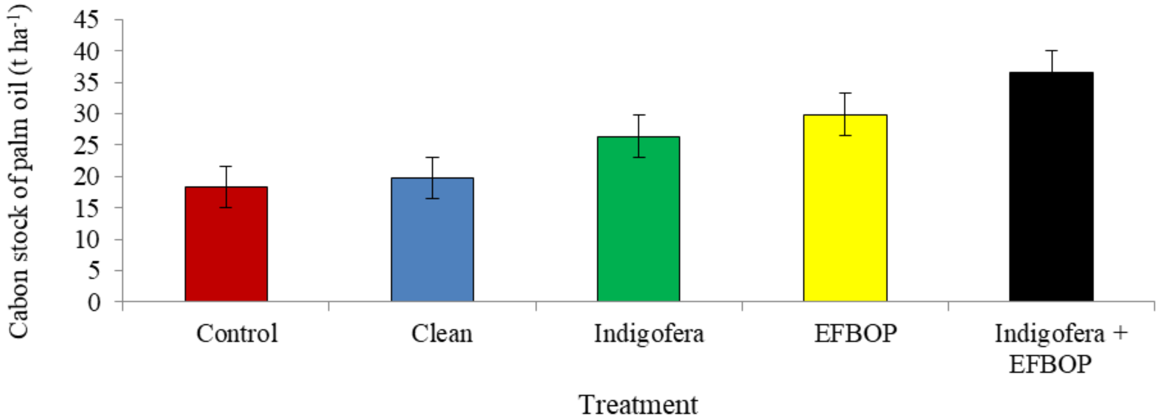

Figure 7. Effects of the treatments on the carbon stocks of palm oil (t ha^{-1})

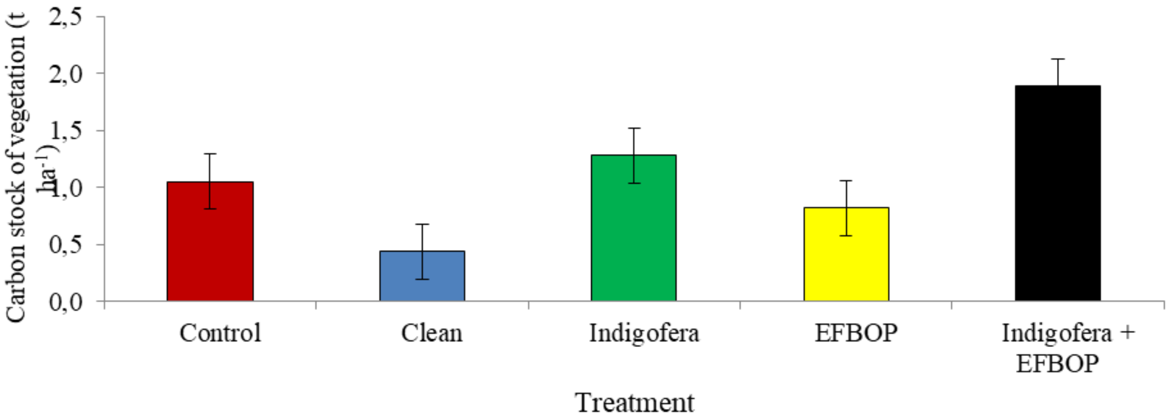

Figure 8. Effects of the treatments on the carbon stocks of vegetation (t ha^{-1})

Table 1. Effects of treatments on respiration and a total population of soil microorganisms

Treatment	Variables	
	Respiration (CO_2-C100^{-1} g soil day^{-1})	Total Microorganism (x 10^5 CFU g^{-1})
Control	61.71	60
Cleaned	65.14	85
Indigofera zollingeriana	66.86	80
EFB	60.00	75
Indigofera zollingeriana + EFB	72.00	105

ing the carbon stocks. The effects of the treatments on respiration and the total population of soil microorganisms can be seen in Table 1.

Soil biological type is directly related to a sustainable farming system because it has an important role in the decomposition process that breaks down complex organic molecules and converts them into available forms to plant (Friedel et al., 2001). Total respiration reflects the activity of soil microorganisms (Pietika et al., 2005). The higher the total soil respiration, the higher the activity of microorganisms in the soil. This study result showed that the treatment of *Indigofera zollingeriana* + EFBOP resulted in higher soil respiration, which was 72.00 CO_2-C100^{-1} g soil on day^{-1} compared to the soil respiration in control, which was only 61.71 CO_2-C100^{-1} g soil of day^{-1}. The increase of microorganisms activity in soil planted with *Indigofera zollingeriana* + EFB is due to its high organic content (Pietika et al., 2005).

The diversity and population of soil microorganisms increased with the treatment of *Indigofera zollingeriana* and EFB. This is in accordance with the research by Broughton & Gross (2000); Malý et al., (2000); Wang et al., (2013), reporting that ground cover plant affects biodiversity and the population of soil microorganism. Gessner et al., (2010) state that soil microorganism population is influenced by litter quality, the amount of nutrients, and plant tissue structure, such as protein and lignin. According to Cesarz et al., (2013), the plant influences the diversity and soil microorganisms population through the carbon supply provided by root exudate.

The treatment of *Indigofera zollingeriana* + EFB resulted in higher carbon stock than other treatments. The highest soil carbon stock was found in the experimental plot planted with *Indigofera zollingeriana* and treated with EFB, which was 81.6 t ha^{-1}, while the lowest soil carbon stock was in the experimental plot cleaned, which was 67.4 t ha^{-1}. Meanwhile, the highest carbon stock of oil palm was also shown in the experimental plot planted with *Indigofera zollingeriana* and treated with EFB, which was 36.60 t ha^{-1}, the lowest one was in the control plot, which was 18.34 t ha^{-1}. The EFB treatment resulted in the highest value of vegetation carbon stock, which was 1.89 t ha^{-1}, while the lowest one was in the cleaned experimental plot, which was 0.44 t ha^{-1} (Hairiah et al., 2001). Carbon stocks of soil, oil palm, and vegetation under oil palm due to the treatments given in the study can be seen in Table 2.

The difference between the treatments given on the carbon stock of soil can be seen in Figure 6. Carbon stock is the amount of carbon stored in an ecosystem at a certain time, both in the soil, plant biomass, and carbon stored in vegetation (Agus, 2011). Ohkura et al., (2003), stated that soil carbon content is affected by the soil's physical properties and the type of vegetation that grows on it. Plants save carbon by absorbing carbon from

Table 2. Effects of the treatments on the carbon stocks of soil, oil palms and vegetation under 5-year-old oil palm

Treatment	Carbon stock (CO_2) (t ha^{-1})		
	Soil	Oil palm	Vegetation
Control	74.4b	18.34b	1.05bc
Cleaned	67.4b	19.75b	0.44d
Indigofera zollingeriana	74.6b	26.36ab	1.28b
EFBOP	72.3b	29.87a	0.82c
Indigofera zollingeriana + EFBOP	81.6a	36.60a	1.89a

Remarks: Values followed by the same letters in the same column are not significantly different based on the DMRT test at α level of 5%.

the air through the process of photosynthesis into constituents of plant tissue. When leaves, twigs, or whole plants die, this material is then returned to the ground and undergoes decomposition (Robert, 2001). Azham (2015) reported that the number of components making up carbon stocks found in vegetation was 5,834 t ha^{-1}, and 22% of the ground cover was shrubs under pioneer vegetation. Thus, some crops must be grown on land to balance the amount of free carbon in the air.

Figures 7 and 8 show that the highest carbon stocks were obtained in the experimental plots planted with *Indigofera zollingeriana* and treated with empty bunches of oil palm.

CONCLUSIONS

The measurement of soil moisture content showed that the experimental plots treated with *Indigofera zollingeriana* + EFB retained water more than the plots with other treatments. The highest soil moisture content in the dry month was shown in July, which was 28.78% at a depth of 20 cm. The highest carbon stocks of oil palm and soil were obtained in the treatment of *Indigofera zollingeriana* + EFB, 81.6 t ha^{-1} and 36.60 t ha^{-1}, respectively. The activity and population of soil microorganisms in the experimental plots treated with *Indigofera zollingeriana* + EFB were higher than in other treatments. The highest respiration was 72.00 CO_2-C 100^{-1} g of soil day^{-1}, and the highest total microorganism was 105 x 105 g^{-1}. The implications of the research results on the current environmental conditions are environmentally friendly, increasing soil fertility and increasing FFB production.

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