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ECOLOGICAL MULTIFUNCTION OF INDONESIAN OIL PALM PLANTATIONS

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RESUME

Currently, environmentalists are more interested in highlighting the impact of oil palm expansion on the environment, such as deforestation, biodiversity loss, and others. Whereas the phenomenon of deforestation is carried out by all economic sectors, the data also shows that the share of oil palm plantations is relatively small in global deforestation. These environmentalists may also ignore the environmental functions, that are inherent in oil palm plantations, such as the green function and blue function, in the concept of multifunctional agriculture. At least five ecological functions of oil palm plantations exist, namely: (1) the biological function of harvesting solar energy; (2) the function of preserving the carbon cycle (carbon sink and sequestration) and preserving the oxygen cycle; (4) the function of preservation the hydrological cycle; (4) the soil and water conservation function; and (5) the function of preserving the germplasm and multifunctionality of oil palm across generations. Oil palm plantations' characteristics as perennial plants with relatively large and tall sizes, canopy cover approaching 100 percent, and a plant age cycle of around 25 years have implications for their ecological functions and benefits. The ecological functions and benefits of oil palm plantations similar or even exceed those of industrial plantations (timber plantations) or even exceed the ecological functions and benefits of forests. So, the multifunctionality of oil palm plantations is not only successful in preserving between generations but also succeeds in enlarging and expanding the benefits that can be enjoyed across generations, both in local, national and global level.

INTRODUCTION

The mainstream of environmental paradigms related to oil palm plantations has only looked at the environmental impact of the expansion of oil palm plantations. Most environmentalists are more interested in highlighting the impact of oil palm expansion on the environment, such as deforestation, biodiversity loss, and others (Wicke, 2008; Vijay et al., 2016). Even though any sector or industry (not only the palm oil industry) converts forests and causes impacts like deforestation, biodiversity loss, and others. The phenomenon of forest conversion into other sectors (deforestation) has occurred since the pre-agricultural era (in the 1600s) in various parts of the world (Houghton, 1999; Walker, 1993; Bhattarai and Haming, 2001).

The European Commission's research (2013) reveals that the involvement of palm oil in global deforestation is relatively small, at less than 5 percent. Therefore, it is too tendentious if environmentalists link the expansion of oil palm plantations to global deforestation and biodiversity loss.

The environmental paradigm that only sees environmental impacts of oil palm plantations is not only misguided, but also ignores the environmental functions that are inherent in oil palm plantations. Agriculture, including plantations, has multifunctions, including environmental service functions, namely green and blue functions multiple (OECD, 2001; Huylenbroeck et al., 2007; Moon, 2012). The green function is related to carbon sinks, sequestration and oxygen production. Meanwhile, the blue function is related to hydrological preservation and soil and water conservation.

Oil palm plantations' characteristics as perennial plants with relatively large and tall sizes, canopy cover approaching 100 percent, and a plant age cycle of around 25 years have implications for their ecological functions and benefits. The ecological functions and benefits of oil palm plantations similar or even exceed those of industrial plantation (timber plantations) or even exceed the ecological functions and benefits of forests. The benefits of green function and blue function can also be enjoyed by the global community for at least one planting cycle, or about 25 years.

At least five ecological functions of oil palm plantations exist, namely: (1) the biological function of harvesting solar energy; (2) the function of preserving the carbon cycle (carbon sink and sequestration) and preserving the oxygen cycle; (4) the fuction of preservation the hydrological cycle; (4) the soil and water conservation function; and (5) the function of preserving the germplasm and multifunctionality of oil palm across generations. These ecological functions and benefits are the basis of the economic function of oil palm plantations, namely as a producer of palm oil and biomaterials. The development of oil palm plantations across generation needs to be seen as a mechanism for preserving the ecological functions of oil palm.

This article will discuss the various ecological functions inherent in oil palm plantations. Various literature related to the ecological functions of oil palm plantations is used to explain it.

THE FUNCTION OF HARVESTING SOLAR ENERGY

Oil palm plantations are part of the link between the sun as source of energy in the universe, and humans. Through the process of photosynthesis in oil palm plants, the energy (photons) from the sun is captured, harvested, and stored in the form of chemical energy, namely palm oil and biomass.

Comparing the ability to harvest solar energy between oil palm plantations and forests (Table 1) shows that oil palm plantations are relatively superior to forests in terms of photosynthetic efficiency, radiation conversion, incremental biomass and dry matter productivity.

Table 1: Solar Energy Harvesting Functions of Oil Palm Plantation Versus Forest

Indicator	Tropical Forest	Oil Palm Plantation
Leaf area index	7.3	5.6
Photosynthetic efficiency (%)	1.73	3.18
Radiation conversion efficiency (g/mj)	0.86	1.68
Total biomass in area (tonnes/ha)	431	100
Incremental biomass (tons/ha/year)	5.8	8.3
Dry matter productivity (tonnes/ha/year)	25.7	36.5

Source: PPKS (2004, 2005)

Likewise in the context of harvesting solar energy in the form of vegetable oil. Oil palm plantations are the most efficient vegetable oil crop to harvest and store the solar energy in the form of oil compared to other vegetable oil crops. Oil productivity from oil palm plantations reaches 4-5 tons of oil per hectare, while the productivity of oil produced from other vegetable oil crops (soybean, rapeseed, sunflower) is only about one tenth.

With the ability to harvest solar energy from oil palm plantations, it provides benefits for Indonesia as a country that has extensive oil palm plantations that are spreading from Sabang to Merauke. With a tropical area from east to west, Indonesia has a long day of 15 hours with a strong intensity of sunlight. With the long duration of radiation, Indonesia, through oil palm plantations, can harvest solar energy for longer and at a higher quality than other countries.

THE CONSERVATION OF CARBON AND OXYGEN CYCLE

In the planet's ecosystems, the total terrestrial carbon stock is estimated to be around 3170 gigatons (Gt), consisting of 2500 Gt of carbon in soil, 560 Gt of carbon in plants, and about 110 Gt of microbial biomass. Meanwhile, the carbon stock in the oceans reaches 38 000 Gt and the carbon pool in the Earth's atmosphere is around 760 Gt. Carbon stocks in the earth's atmosphere, both terrestrial and oceanic are linked through the carbon cycle (Jansson et al., 2010; The World Bank, 2012).

Oil palm plantations are part of the chain of sustainability in the carbon cycle in the planet's ecosystem, which has a very important role. Through the process of photosynthesis assimilation, palm oil plants absorb CO_2 from the atmosphere (Table 2), where most of the carbon is used for respiration and partly stored in the form of biomass (Hardter et al., 1997; Henson, 1999; Fairhurst and Hardter, 2003). Oil palm trees are an annual plant (perennial plant) with a root system that is intensive, relatively large in size, rapid growth, and high production and cropping cycles for 25 years or more, thus making oil palm plantations "biological machines" to absorb large amounts of CO_2 from the Earth's atmosphere.

Table 2. Carbon Dioxide Absorption and Oxygen Production of Oil Palm Plantation Versus Forest

Indicator	Tropical Forest	Oil Palm Plantation
Gross Assimilation (Ton Co_2/Ha/Year)	163.5	161.0
Total Respiration (Ton Co_2/Ha/Year)	121.1	96.5
Net Assimilation (Ton Co_2/Ha/Year)	42.4	64.5
Production of Oxygen (O_2) (Ton O_2/Ha/Year)	7.09	18.70

Source: Henson (1999)

The net absorption of CO_2 in oil palm plantations is greater than in tropical forests. Because tropical forests are generally in a steady state where the rates of photosynthesis and respiration are balanced. On the other hand, the rate of photosynthesis in oil palm plantations is still much higher than the rate of respiration (Hardter et al., 1997; Fairhurst and Hardter, 2003).

As part of the carbon cycle of the planet's ecosystem, oil palm plantations have the ability to absorb carbon (carbon sinks) on a net basis of 64.5 tons of CO_2/ha/year. With these capabilities, the total area of Indonesian oil palm plantation is 16.3 million hectares, and has absorbed 1.03 Gt CO_2 from the earth's atmosphere.

Carbon absorbed by oil palm plantations through the biosequestration mechanism is stored in the biomass, both in the oil palm biomass itself (above ground biomass) and in the underground biomass of the root system, which is then stored as organic carbon and soil inorganic carbon.

Chan (2002) calculated the amount of biomass and carbon stock (above ground biomass) resulting from carbon sequestration in oil palm plantations, with variations in carbon stock ranging from 5.8 tons per hectare (on immature plants) to 45.3 tons per hectare (at the age of 20–24 years), or an average of 30 tonnes of carbon per hectare. Meanwhile, the study by Kusumawati et al. (2021) found that one-year-old oil palm plantations contained a carbon stock of 43.5 tonnes per hectare and that 28-year-old oil palm plantations had a carbon stock of 74.7 tonnes per hectare. The Khasanah study (2019) also revealed that the average carbon stock in above-ground biomass in Indonesian oil palm plantations reached 40 tons per hectare.

The photosynthetic process that occurs in oil palm plantations is also part of the function of the sustainability of the oxygen cycle in the planet's ecosystem. Through the process of photosynthesis, oil palm plantations recycle carbon dioxide and water into oxygen, which is then supplied to the planet's ecosystems. Photosynthetic oxygen production of oil palm plantations is estimated at 18.7 tons of O_2 per hectare (Table 2), or higher than the capacity of the forests to produce oxygen. This is related to the ratio of the rates of photosynthesis and respiration in forests compared to oil palm plantations.

With an area of 16.3 million hectares of Indonesian oil palm plantations, these plantations are also capable of producing around 305 million tons of oxygen. The function of preserving the carbon dioxide and oxygen cycle can also be described by the function of oil palm plantations as the "lungs" of the ecosystem (PASPI Monitor, 2021). Just as the function of the lungs in the human body is to supply oxygen into the cells and remove carbon dioxide from the body's cells, so does the function of oil palm plantations in the ecosystem. Oil palm plantations supply oxygen to the earth's atmosphere and absorb carbon dioxide from the earth's atmosphere. The function of the "lungs" is played by oil palm plantations from generation to generation for free.

CYCLE PRESERVATION AND SOIL-WATER CONSERVATION

Oil palm plantations are also part of the preservation of the hydrological cycle as well as soil and water conservation. Oil palm plantations, through the evapotranspiration mechanism, have an important role in the hydrological cycle in the planet's ecosystems. Evapotranspiration is the link between water from the soil and water vapor in the earth's atmosphere. Several hydrological indicators of oil palm plantations compared to forests are presented in Table 3.

Oil palm plantations naturally or inherently have the ability to be soil and water conservation plants (Harahap, 2007). Two natural mechanisms of soil and water conservation in oil palm plantations are the mechanism of the leaf midrib structure (canopy cover) and the mechanism of the root system in oil palm plants. These two capabilities, coupled with Good Agricultural Practices (GAP) on soil and water in plantation management as part of man-made conservation, make oil palm plantations become a part of the soil and water conservation system in an area.

Table 3. Comparison of Hydrological Indicators between Oil Palm Plantations and Forests

Indicators	Tropical Forest	Oil Palm Plantations
Evapotranspiration (Mm/Year)	1560-1620	1610-1750
Groundwater Reserves until the Depth of 200 Cm (Mm)	59-727	75-739
Rainfall Continuation Toward Soil Surface (%)	85	87
Solum Layer Infiltration Rate 0-40 Cm (Ml/Cm^3/Min)	30-90	10-30
Air Humidity (%)	90-93	85-90

Source: Henson (1999), PPKS (2004, 2005)

The mechanism of the structure of the leaf midrib of oil palm trees in layers is able to cover the land around 100 percent since the immature plant. Each oil palm tree produces 18–30 fronds every year. For young plants (less than 8 years old), the number of fronds should be kept in the 48–56 range to ensure optimal photosynthesis and productivity. Meanwhile, in old plants (> 8 years old), the number of fronds must be maintained in the range of 40–48 fronds (Turner and Gilbanks, 1974; Harahap, 2006; Harry et al., 2016). With the number of fronds maintained, it will form a canopy system that "overshadows" (canopy cover) almost 100 percent of the oil palm plantation area.

The structure of the leaf midrib, in addition to functioning as the "kitchen" (photosynthesis) of oil palm, also serves to protect the soil from direct rainwater. If it rains, the raindrops don't hit the ground directly but are protected and split by the layered structure of the leaf frond.

Oil palm plants also have a massive, broad, and deep fibrous root system (Harahap, 1999, 2007; Harianja, 2009). Mature oil palm roots can reach a radius of 4 meters around the base with a depth of up to 5 meters below the soil surface, which forms micro and macro soil pores (Harahap, 1999). The micropores and macropores of the soil, or biopores, increase as the plants mature.

As the age of the oil palm plant increases, the roots become wider and deeper, so that the pores of the soil that store organic matter and groundwater are also getting bigger. Mature oil palm trees have roots that reach more than 5 meters, with a depth of more than 5 meters from the base of the oil palm trunk. Water filled in the rainy season will be stored in the soil pores of the oil palm plants, creating a large enough water reserve. When the dry season arrives, the water reserves are slowly released, both for the needs of the oil palm plant itself and other plants around it, as well as for the needs of soil microorganisms. On the other hand, during the rainy season, rainwater that falls on palm oil fields is absorbed to fill the "reservoir" of soil pores as water reserves.

This biopore system and mechanism of oil palm cause the its plantations to have a good ability become water holding capacity. Such a natural biopore system makes oil palm plantations soil and water conservation plants. According to research by Allen et al. (1998) and Rusmayadi (2011), the water holding capacity of oil palm land is better than that of rubber plantations, so the water content of oil palm plantations is higher than rubber plantations.

These natural biopores increase the ability of oil palm plantations to absorb and hold water (water holding capacity) by increasing rainwater infiltration into the soil, reducing surface water run-off and storing water reserves in the soil. The percentage of continuation rainfall to the soil surface, the rate of infiltration of the solum layer and groundwater reserves to a depth of 200 cm in oil palm plantations are relatively similar compared to forests (Henson, 1999; PPKS, 2004, 2005).

In addition to absorbing water, the biopores formed in the rhizosphere of oil palm also store organic matter. The content of organic matter and C-organics in the root of oil palm is increasing along with the age of the oil palm plant (Harianja, 2009).

The mechanism for soil and water conservation in oil palm plantations can also be done through land management in oil palm cultivation (man-made conservation). Technical culture standards for oil palm plantations start with planting and maintaining plants using soil and water conservation principles. Planting legume cover crops during the maintenance of immature plants (age 0–4 years) has the function of conserving soil and water, as well as increasing soil fertility (Prawirosukarto et al., 2005; Yasin et al., 2006).

The terrace system on sloping land, the manufacture of horseshoe plates, the placement of pruning fronds as mounds of organic matter in the mounds, rorax, mulch, returning empty bunches and liquid waste to the land are part of the GAP for oil palm plantations, which is also a part of the soil and water conservation mechanism in oil palm plantations (Satriawan et al., 2015; Afandi et al., 2017; Murtilaksono et al., 2018; Satriawan et al., 2021).

Utilization of biomass on land is also part of soil and water conservation. One of the results of oil palm cultivation is that biomass has a faster growth rate than forest biomass (Henson, 1999). The volume of biomass in oil palm plantations increases with the age of the oil palm plantations. In immature plants, the volume of biomass is around 14.5 tons per hectare and continues to increase to around 113 tons per hectare (Chan, 2002). Most of the biomass returns to the oil palm plantation area during the maintenance process and during theperiod replanting to add organic matter to the land. Besides functioning to increase soil fertility, the addition of organic matter is also an important part of water and soil conservation.

The soil and water conservation mechanisms in oil palm plantations last quite a long time, from planting to the next 25 years (replanting). So, the mechanism and benefits of soil and water conservation in oil palm plantations also last up to 25 years. Oil palm plantations are an important part of the regional soil and water conservation system.

MULTIFUNCTION AND GERMPLASM CONSERVATION

Oil palm plantations across generations are a vehicle for conserving oil palm germplasm and the multifunctionality inherent in oil palm plantations. The development of oil palm plantations in Indonesia began with four varieties (2 varieties from Bourbon-Mauritius and 2 varieties from Amsterdam), which were planted as collection plants in the Bogor Botanical Gardens in 1848.

By 2020, or 172 years later, these four varieties had grown to 58 (registered with the Ministry of Agriculture). This shows that through the cultivation process in the plantations, they are not only able to preserve the 4 original oil palm varieties, but instead develop them into 58 varieties. This is concrete proof of sustainability. At least in the case of oil palm plantations, the preservation of germplasm through cultivation is much more successful than conservation methods like In Situ and Ex Situ.

Apart from being successful in preserving germplasm, oil palm plantations have also succeeded in preserving the multifunctionality (OECD, 2001; Huylenbroeck et al., 2007; Moon, 2012) built into oil palm, both in terms of economic function (white function), environmental function (green function), and social function (yellow function). Oil palm plantations are not only sustainable from generation to generation, but also increasingly widely enjoyed by the global community.

The economic function has developed not only as food production but has also expanded into energy materials, biosurfactant raw materials, biolubricants, nutriceuticals, and others. Likewise, social functions are no longer limited to just a vehicle for rural social cohesiveness but have evolved to create job opportunities and eliminate poverty at the local, national, and global levels.

In other words, the preservation of germplasm and its multifunctionality through oil palm plantations has not only succeeded in conserving across generations but has also succeeded in enlarging and expanding the benefits that can be enjoyed across generations. Oil palm plantations are a good example of sustainability.

CONCLUSION

Oil palm plantations have ecological functions that provide multiple benefits for the community across generations. Oil palm plantations function as solar energy harvesters, harvesting solar energy and storing it in the form of oil.

Through its functions as a carbon sink and carbon sequestration, which are important in the carbon cycle and carbon stock in the planet's ecosystem, oil palm plantations are part of the function of preserving the carbon cycle in the planet's ecosystem. Oil palm plantations also play a role in the preservation of the oxygen cycle, as well as soil and water conservation.

Oil palm plantations also have a function as germplasm conservation and are multifunctional in social, economic, and environmental aspects across generations. Preservation through oil palm plantations is not only able to preserve but also be able to increase and expand benefits across generations, both in local, national and global scope.

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