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Potential for developing an intercropping system on oil palm fields in peatlands

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Abstract. Planting using a monoculture method is believed to impact the diversity of plant specieson oil palm plantations, especially on peatlands, so the discourse on cultivating oil palm plantations using a polyculture system is to enrich species and avoid fears of environmental damage. It is necessary to conduct a study to determine the potential impact of an intercropping system between oil palm and other crops on the Land Equivalent Ratio (LER) value, intra and interspecific competition between plants, and reducing soil fertility. Data was obtained through a literature review and Forum Group Discussion (FGD) in a quadruple helix system comprising academia, farmer groups, district plantation services, and companies. Various literature studies showed that polyculture planting with an intercropping system reducesor inhibits palm oil production in peatland, but it can increase LER > 1.5. This is in line with the results of the FGD, which shows that planting using an intercropping system causes delays in palm oil production; consequently, the farmers and palm oil companies prefer monoculture planting. However, from the results of the FGD, a solution was obtained to overcome the aboveproblems by arranging the planting distance when planting was planned, namely with a broaderdistance of 10 x 10 m or with a population of 100 -110 plants per hectare, so that there is enoughspace to carry out intercropping and reduce competition. The results showed that polyculture planting with an intercropping system could also enrich plant species, apart from having the potential to increase LER > 1.5.

1. Introduction

Palm oil is one of the plantation commodities in Indonesia that is increasing, with a land area of 16.2 million ha [1]. It contributes quite a large amount of foreign exchange to the nonoil-and-gas sector. Ownership of oil palm plantations in Indonesia is divided into three types: state-owned plantations, private plantations, and plantations managed by smallholders. The productivity gap is entirely accurate in smallholder plantations with the lowest average productivity, namely 2.41 tons of CPO/ha or 82.8% lower than the national average in 2018. Studies of land feasibility and production factors in smallholder plantations show that the potential of palm oil productivity can reach more than 29.1 tons of FFB/ha. However, in actual conditions, it only reaches 15.3 tons of FFB/ha or around 53% of the potential that can be achieved [2]. Many factors cause the low productivity of smallholder plantations, such as inappropriate fertilization and technical culture, as well as plants that are past their productive period

(>20 years). Replanting technique usually implement to replace unproductive plants with new ones. This activity requires significant costs and causes a loss of income for planters when the palm oil is not yet mature. This causes many smallholders to postpone replanting activities. There are various alternatives to increase smallholder income during the immature plants (IP) period, one of which is through implementing an intercropping system during the IP period for oil palm plantations with horticultural or annual crops [3][4][5]. In the IP phase (0-3 years), the canopy and plant root development has not yet reached the optimal phase, so there is a significant opportunity to utilize open land space for intercropping planting with conditions of adequate sunlight interception and minimal nutrient competition. By paying attention to this, planting of inter-season crops on oil palm plants aged 0-1 years can be carried out with an area of up to 50-80%, aged 1-2 years by 35-50%, and aged 2-3 years by 15-35% at commonly used oil palm distance [6].

The study of [15][16][17] show that the intercropping system have a positive impact on increasing profits, finance, and economics, especially in the IP period. However, previous research shows that the intercropping system with annual crops found several obstacles: the phenomenon of N, P and K nutrient deficiencies that occur in IP plants [18][19]. Nutrient deficiencies arise due to changes in status nutrient fertility, unfulfilled nutritional needs of main-plants and intercrops, as well as there is competition for nutrients between them [18].

The intercropping system in oil palm plantations on peatlands needs to pay attention to soil fertility and sunlight intensity. Soil fertility levels are improved through fertilization and amelioration. Ameliorants such as dolomite, organic materials, etc., are needed to increase productivity by increasing soil pH, Ca, and Mg content. Problems with light intensity can be anticipated by planting shade-tolerant species, such as soybeans.

This study aims to analyze the factors that need to be considered in developing an intercropping system on peatlands using various literature studies and group discussion forums (FGD) with stakeholders of farmer groups, academics, local governments, and companies.

2. Research Methodology

The research was conducted in Barito Kuala (Batola) Regency, South Kalimantan, by holding Forum Group Discussion (FGD) among the stakeholders which are farmer groups, academia, local government (Batola Regency Plantation Service Department), and also private sectors. The farmers involved consisted of twenty-five (25) farmers five (5) academia, 1 researcher from National Research and Innovation Board, five (5) Batola Plantation Services Department officer, and three (3) representatives from the private sector. The FGD aims to gather information from stakeholders about the importance of using land around oil palms with an intercropping system, the obstacles, and the benefits. This study also cited several relevant journals and books to support the results of the FGDs.

3. Result and Discussion

3.1. Result

3.1.1. Obstacles to Implementing Intercropping on Peatlands

The need for palm oil continues to increase along with the increasing world demand for CPO, as has happened in the last few years, especially in line with the growing need for derivative industries such as bioenergy development as an alternative fuel [7]. This encourages investors from within the country and abroad to build oil palm plantations in Indonesia on both mineral and peat soils.

The demand for oil palm fruit means more land is needed to plant oil palm, while mineral land is limited. Based on data from BBSDLP in 2011, Indonesia has 14,905,574 hectares of peatland spread across Sumatra, Kalimantan and Papua. 40-50% of peat land has the potential to be developed for agriculture and plantations. Therefore, peat land management is needed to implement on oil palm plantation. Peatland is land with water-saturated soil, formed from sediment originating from the accumulation of decaying tissue residues of the past with a thickness of more than 50 cm (Indonesian National Standard Draft-R-SNI, National Certification Agency 2013). Peatlands have a high organic content (carbon compounds) with 6-91% in all layers. Not all plants can grow on peatland. Oil palms is one of them that can grow well on peatland. Peatland is a potential land for oil palm plantations. Oil palm production on peatlands can reach 20 – 25 tons FFB/ha/year, which is no less than oil palm production on other soil types. Based on data from the Directorate General of Plantations, Ministry of Agriculture (2011), the peat land area used to develop oil palm plantations up to 2011 was 1,539,579 ha.

Table 1. Area of Oil Palm Plantations on Peatlands until 2011

No.	Pulau	Luas (ha)	%	Average Palm Fruit Bunch Productivity (FBP) (tons/ha)
1	Sumatra	1,249,105	23.4	2.6-4.0
2	Kalimantan	288,136	13.8	2.4-3.7
3	Papua dan Papua Barat	48,920	3,3	2.5-2.8

Most of the oil palm plantations in Indonesia are on mineral soil with an area of 6,170,546 ha or 80%, while peatland only covers an area of 1,539,579 ha or only 20% [7]. Oil palm planted on peatland has higher fire exposure than oil palm plants grown on mineral land. During the dry season, the groundwater level in peatlands decreases naturally, resulting from the drainage system. Hence, the peat soil layer (especially thick peat) becomes very dry and flammable. Analysis of historical fire data in Global Forest Watch Fires also confirms that fires tend to be concentrated in agricultural concessions and peatlands in Indonesia.

The soil fertility level is also a differentiator for classifying peat into several groups [51]. The grouping is based on peat ash content, namely (a) eutrophic is peat with a high level of fertility or ash content >8%, (b) mesotrophic is peat with a medium fertility level or has an ash content >2% to 8%, and (c) oligotrophic is peat with the lowest fertility level or ash content ≤2%. Based on these criteria, the peat found on Kalimantan Island is generally oligotrophic.

Oil palm plantations planted on mineral lands fire at the soil surface, while on peatlands, fire below the ground surface. This happens because the peat layer below the surface is more easily burned if it experiences dryness due to the raw nature of the peat (in the form of fibres or fibrists). In contrast, peatlands on the upper surface are relatively more mature (saprist or hemist). Therefore, handling fires on peatlands is different from mineral lands.

According to farmers, some places during the rainy season are flooded with water, and during the dry season, there is drought. This occurs due to the subsidence of peat, so the function of peat to absorb water during the rainy season and release water during the dry season does not work. Land subsidence is a challenge in the long-term management of plantations on tropical peatlands. Over time, land subsidence increases the risk of periodic flooding and inundation, which then has the potential to reduce productivity. Land subsidence occurs due to the shrinkage of dry peat and accelerated peat decomposition caused by exposure to oxygen. This oxidation can then cause CO_2 emissions from drained peatlands.

The result of this subsidence causes waterlogging during the rainy season so that intercrops planted between oil palms die; this is, of course, different from oil palms, which are resistant to waterlogging. This is the reason farmers consider why they do not use an intercropping system. In addition, during the dry season, peatlands dry out quickly because surface water quickly evaporates and dries up, so that intercrops die. Differences in subsidence rates are related to the average water level, where the water level factor is proven to be more influential than other factors such as peat depth, plantation age and vegetation type.

Significant changes in land cover, such as those observed in areas where plantations and industrial forest plantations are very extensive, can spatially show the expansion or extensification of peatlands. They are extensively developed. Peat is physically soft and has a low load-bearing capacity [8]. If drained, peatlands will experience subsidence (decrease in surface), have the potential to dry out irreversibly (irreversible drying) and have an impact on reducing their water-holding capacity (hydrophobicity). The risk of fire threats will increase. Subsidence rate al. influenced by drainage depth and peat thickness. The deeper the drainage, the faster the subsidence rate. The rawer the peat, the higher the subsidence rate. The subsidence rate is also greatly influenced by the thickness of the peat, whereas in deep peat, the subsidence rate is more significant than in medium peat and shallow peat [9] [10].

The relationship between subsidence and groundwater levels results in apparent changes in potential emissions and decomposition in the soil cross-section. The deeper the drainage, the lower the groundwater level and subsidence occurs. Subsidence also occurs with increasing decomposition and oxidation processes of organic material, which results in more significant emissions. So, it can be said that if the groundwater level is lowered by deepening the drainage channels, emissions will become higher [11].

3.1.2. Soil Acidity and Nutrient Deficiencies.

Oil palm plantations in Indonesia are generally found on dry, acidic land and peatlands. The main inhibiting factors faced in acid dry land are acidic soil reaction (pH 4.0–5.5), high aluminium (Al) content with Al saturation > 25%, low soil organic matter content (< 3%), and availability of low nutrients [12]. This is no different from the obstacles faced in peatlands, namely the acidic soil conditions due to the high level of organic acids that form peat. According to [13] [14], the pH of peat soil reacts acidically related to the decomposition of organic matter in anaerobic conditions, which forms phenolic and carboxylate compounds, causing high peat acidity, which can poison plants and limit nutrient availability, as well as high pest and disease attacks. For this reason, it is necessary to have location-specific soybean cultivation technology to increase soybean productivity. There are three key factors to solve, namely: 1) using adaptive superior varieties, 2) land amelioration, and 3) optimal fertilization.

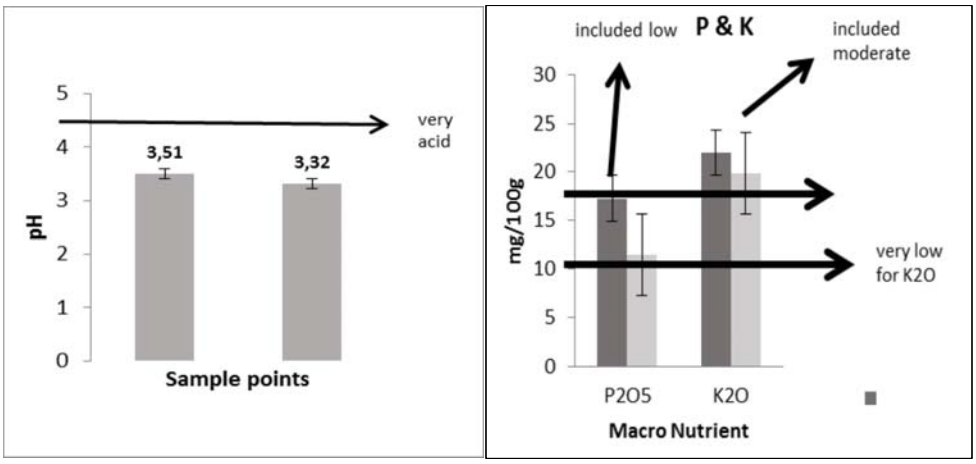

Figure 1. Soil pH and macronutrient content in peatlands.

Figure 1 shows that the soil pH in peatlands is very low, < 4 or very acidic, and tends to be infertile, with the macronutrients N, P and K being very low. The study of [15] [16] [17] shows that the intercropping system has a positive impact in providing financial and economic benefits, especially in the IP period. However, research shows that the intercropping of plantation crops with annual crops carried out previously has several obstacles that need special attention, namely the phenomenon of N, P and K nutrient deficiencies in PFB plants [18 [19]. Nutrient deficiencies arise due to changes in nutrient fertility status, unfulfilled nutritional needs of central plants and intercrops, and additional nutrient competition [18].

The availability of nutrients in peat soil varies greatly. The essential elements in peat in one place are found in the low category. Still, in other areas, they are in the high category, while N and P are in the medium to very high category but are not immediately available to plants [20] [26] [24]. The P problem faced in peat development is the low P storage capacity [26] and the P supply capacity, which is also low [20] [21] [22], so a strategy to increase capacity is needed. Available P through effective P adsorbing compounds, 45 Journal of Land Resources Vol. 11 No. 1, July 2017; 43-52 use of natural phosphate and timing of ameliorant and P fertilizer application, so P fertilization becomes more efficacious [23]. The availability of microelements in peat is classified as low to very low [24] [25]. The cation exchange capacity (CEC) of peat is classified as high to very high. This is because H+ dominates the CEC value in peat and is also a source of acidity. Peat soil is known to have a high CEC value, but this does not reflect the high availability of alkaline elements. CEC value of peat ranges from 40-180 cmol (+) kg-1 [26] [24] [25] Competition Between Oil Palm and Intercrops. The FGD results found that planting with an intercropping system can inhibit the production of palm fruit; this happens because planting with an intercropping system will cause intra- and interspecific plant competition, thereby causing delays in oil palm production and the growth of intercropping [27]. The research results of [6] show that planting using an intercropping system does not affect soil fertility or harmless plant growth, so it is feasible to implement.

In the phase (0-3 years), the development of the canopy and plant roots has not yet reached the optimal phase, so there is quite a significant opportunity to utilize open land space for planting intercrops with conditions of adequate sunlight interception and minimal nutrient competition. By paying attention to this, planting of inter-season crops on oil palm plants aged 0-1 years can be carried out with an area of PFB up to 50-80%, aged 1-2 years by 35-50%, and aged 2-3 years by 15- 35% at average plant distance [6].

The combination of oil palm plants with other plants (interspecific) cannot yet be determined whether it is independent (plants do not influence each other), competitive (an increase in the yield of one plant species results in a decrease in the yield of another), allelopathy (occurs due to secretion/excretion/toxic substances released by certain types of plants in a commodity) or stimulation (the productivity of a plant will be increased due to the presence of another species). The characteristics of this combination can be determined from field observations based on plant growth and production. Intercrops between oil palm plantations include cultivating food crops, plantations and horticulture as intercrops between oil palm plantations, which have an excellent opportunity to be carried out. The type of intercrop and the form of farming depends on the available resources and market demand. The resources are land and climate conditions, oil palm plant conditions, and technological status. At the same time, the form of farming is determined by the farmer's social culture, economy, and market demand [28]. Oil palm intercropping has several advantages, including optimizing land use as directed by the land equivalent ratio (LER), producing diverse products, obtaining additional yields, improving soil fertility, and preventing erosion.

3.1.3. Selection of Intercropping Plants.

Commodity selection is closely related to overflow typology, seasonality, commodity economic value, and technology availability. Land planning in production areas opens up opportunities to cultivate commodities such as rice, corn, soybeans, oranges, vegetables, coconuts, rubber and palm oil. Horticultural commodities (vegetables and fruit) have higher economic value than food crops but require more intensive cultivation techniques [29].

Another consideration when using shallow peat is the plant root system. Annual plants are not recommended for cultivation on this land because they require a broader and deeper root area. The thickness of shallow peat is limited, so it is hazardous if the roots of annual plants touch the soil's lower layer containing toxic compounds. Likewise, if the peat substratum is quartz sand, which is poor in nutrients, it requires more nutrient input and organic fertilizer. Besides that, sandy soil has a low water retention capacity, so it requires more water input, and the risk of plants drying out or wilting is greater.

Therefore, shallow peatlands are only used for cultivating food and horticulture crops.

Oil palm plants have fibrous roots. This root system absorbs nutrients in the soil and plant respiration media. The stem of the oil palm plant is cylindrical, with a diameter of 25-75 cm, growing straight from the tuber. Its phototrophic nature (the nature of seeking sunlight) makes oil palms grow taller quickly if protected. The length of oil palm leaves is 5-9 m, with several 125- 200 leaflets and a height of 1.2 m [30]. Oil palm plants have a productive life of 25 years; in oil palm cultivation activities, there is a period called Immature Crops (IP), which lasts 3-5 years, depending on the variety of oil palm planted. During IP, farmers will continue to incur costs for plant maintenance such as fertilization, eradicating pests and diseases, labor and so on. Land use during IP can be done by implementing intercrop cultivation.

Figure 2. Intercropping system in peat swamp land in Batola Regency, South Kalimantan.

Various literature shows that intercropping in oil palms can occur in annual plants. Annual crops that can be planted include food crops, such as corn, rice, soybeans and cassava and horticulture vegetables, such as chili, bitter melon (pare), shallots and fruits, such as watermelon, pineapple and banana). According to [31], the recommended period for utilizing oil palm land for intercropping is only two years (IP 2 years), considering the growth of oil palm plants and intensive care for oil palm plants. Meanwhile, intercropping in annual plants can include agarwood, white teak, cocoa and rubber. Agarwood is planted between oil palm plants with spacing. Meanwhile, white teak, cocoa, white teak and rubber are planted on the edges of oil palm plantations.

The selection of intercrop commodities for oil palms needs to be considered carefully because not all species of plants are suitable for planting side by side. Several considerations in selecting the intercrop plants include the characteristics of oil palm and intercrop plants, the suitability of the macroclimate for oil palm, the condition of the microclimate under the oil palm, the climate requirements for intercrop, the seasonal pattern of intercrop, market demand, and the use of capital and land [13] and [29] report that peatlands are essential to providing food. Rice, corn and soybeans (Pajale plants) are plants widely cultivated in shallow peatlands [33]. Pajale plants, especially rice, are a type of plant that has long been cultivated by farmers in shallow peatlands. This plant developed because (1) traditionally farmers have mastered its cultivation techniques, (2) water management is more accessible, (3) cultural encouragement to produce food, (4) it becomes the mainstay of the family's economy, and (5) absorbs direct labor or indirectly.

Based on the calculation of the land equivalent ratio (LER), it is found that the polyculture system has an LER value of 1.5. This illustrates that the polyculture system is 50% more profitable or half than the monoculture system. Using an intercropping system, the land equivalency ratio is one way to calculate the productivity of two or more crops planted. This system will be more profitable if LER > 1. If the LER value = 1, it shows that the monoculture system and polyculture system patterns provide the same benefits. This aligns with the opinion [34] that an average LER value of >1 illustrates that mixed cropping is profitable if planted using an intercropping system compared to monoculture.

3.1.4. Water management

One factor that influences fluctuations in groundwater levels is the thickness of the peat [35]. Fluctuations in groundwater levels reached 11.4 - 192 cm in peat domes and 8.6-179.8 cm in the back. Swamp areas. Fluctuations in groundwater levels due to differences in seasons determine the availability of oxygen, the degree of decomposition, the availability and movement of nutrients and metals, and the physical and biochemical properties of the soil [36]. The decomposition rate and population of peat soil microorganisms are greatly influenced by the groundwater level's depth (depth) and height. Fluctuations in groundwater levels affect the distribution and concentration of ferrous (Fe^{2+}) and SO_4^{2-} [37].

Figure 3. Depth of the water table in peatlands

Peatlands have unique properties for each type. Apart from the chemical elements of the soil, the water level in peat fluctuates wildly following rainfall so that during the peak of the dry season, the groundwater level can reach 200 cm below the ground surface. Conversely, during the peak of the rainy season, it can inundate the entire peat soil layer. The three types of land cover in two different physiographists in this study show different soil chemical properties, and fluctuations in groundwater levels determine the intensity or pattern of change.

This is similar to [35], who stated that the fluctuation factors in groundwater level and peat layer thickness could be simultaneous or relatively dominant; only one factor influences the observed soil properties. This is similar to the observed nutrients, which mainly come from the peat layer dissolved through the decomposition mineralization process, or the metal elements, mainly from sulfidic materials under the peat layer. The decrease in groundwater level to the layer of sulfidic material has affected the properties of the sulfidic material beneath the peat layer. As a result, the properties of the sulfidic material at each peat thickness are also different [38] [36].

Groundwater level fluctuations also influence soil redox conditions and Fe concentrations. The decrease and increase in rainfall will reduce the total Fe content from 25% to <1% of the total soil mass. Seasonal changes also influence peat soil's total Fe content and annual rainfall's influence on the Fe content in swamp groundwater [37].

Fluctuations in groundwater levels also influence the value of peat soil's cation exchange capacity (CEC). The CEC value of the peat layer is not influenced by the presence of sulfidic material beneath it [35]. The influence of high groundwater levels on peat soil CEC can be explained as follows. The CEC value of peat soil depends on pH; conversely, it is known that the pH value of peat soil with a sulfidic material substratum is susceptible to high groundwater level fluctuations. Therefore, to improve or increase the quality of peat soil with a sulfidic substrate, what must be considered is the fluctuation of high groundwater level and the thickness of the peat layer so that there is no drastic decrease in pH, which can result in a reduction of the soil's CEC.

Water management is one of the primary keys to an intercropping system for cultivating rice, corn and soybeans in shallow peatlands, especially in regulating groundwater levels [20][33]. Cultivating rice, corn and soybeans in shallow peatlands requires a water depth of 20-50 cm from the soil surface.

This arrangement aims to ensure that plant roots develop well and do not cause flooding (except for rice plants, which at certain phases require flooding) so that the oxygen supply is sufficient. Water management guarantees water availability for plant needs and must maintain good aeration conditions for microorganisms, control soil chemical reactions and plant root development. Rice, corn, and soybeans commodities are usually planted in monoculture and intercropped with plantation crops, such as oil palm and coconut. According to [20][33], to increase the contribution of shallow peatlands in providing food, it is necessary to utilize immature oil palm and coconut plantations and old or damaged plants. Apart from the three commodities above, cassava and sweet potatoes are widely cultivated in shallow peatlands [39][33]. These two commodities are growing because. Generally, these plants do not require specific growing conditions, especially those related to nutrients and attacks by plant pests. They do not require intensive care, so farmers have more free time for other activities.

From the description above, peat soil's properties tend to change to form a specific pattern that adapts to fluctuations in groundwater levels. However, groundwater level fluctuations also consistently unaffected peat soil properties because other factors influence them more [35]. Each element observed has unique properties in responding to the dynamics of groundwater level fluctuations so that a natural balance condition is always achieved; however, in general, it can be said that groundwater level fluctuations are more dominant in influencing the chemical properties of peat soil with a sulfidic material substratum compared to other factors like peat thickness [35].

3.2. Discussion

Peatland use is carried out dynamically due to fires and other factors, causing the peat thickness to decrease to less than 100 cm. It is indicated that the potential area of thin peatland is still significant. However, its utilization is still limited due to its scattered existence and limited accessibility, so it is economically less profitable, even though various technologies to utilize this land are available [39 [40]. Farmers use thin peat more often for cultivating food and horticultural crops than other plant types [41]. It is estimated that 50-60% of food and horticultural crop production is produced from this land, so it has excellent potential to become a food supplier in the future. The use of thin peatlands to supply more massive food requires information about its potential and use for food crops and cultural horticulture.

According to PP Number 57 of 2016 concerning Amendments to PP Number 71 of 2014 concerning the Protection and Management of Peatland Ecosystems, peatland ecosystems have a protective function and a cultivation function. Peatlands with a depth of more than 3 (three) meters are included in the protected category. Therefore, clearing land cover and creating drainage are not permitted. Clearing activities, clearing land and creating drainage (channels) cause changes in the water system [42]. This influences the fertility level of peatlands, land subsidence, and drying out that does not return, turning into plantations and industrial forest plantations (HTI), which are land covered with monogenous (one type) vegetation.

Peatland productivity is very dependent on management and human actions. Peatlands are known as land that is fragile or susceptible to changes in unfavorable characteristics. Peatland management needs to be careful to avoid changes in factors that cause land productivity to decrease, let alone make it unproductive. One consideration when using peatland is the thickness of the peat. According to [44] [45] [46], peatlands with a thickness of 50-100 cm are classified as shallow/thin peatlands. The thicker the peat, the lower its potential for cultivating food crops. Around 5,241,473 ha or 35.17% of Indonesia's total peatland area is classified as shallow peat [46], spread across Papua Island (2,425,523 ha), Sumatra Island (1,767,303 ha), and Kalimantan Island (1,048,611 ha).

Research [47] shows that corn's productivity as an intercrop in oil palm areas is 0.9-2.6 tonnes/ha, with income ranging from IDR 1.9-5.2 million per planting season. Research [48] shows that banana farming as an intercrop in coconut plantation areas is IDR 3,212,000/ha. In contrast, corn farming as an intercrop in coconut plantation areas is IDR 1,608,950/ha. Corn and Banana commodities as intercrops show a value greater than one (R/C ratio > 1). This indicates that cultivating corn and bananas as intercrops is feasible for smallholder plantation farmers in oil palm IP areas. This is supported by research [30], which obtained an R/C ratio of 1.76, and [49], which received an R/C ratio of 2.98 for cultivating corn as an intercrop in oil palm areas. The R/C ratio for cultivating banana plants as intercrops in PFB rubber plantations [50] is 1.28. The R/C ratio value for the cultivation of barangan bananas (3.51) is more significant when compared to the cultivation of corn (2.25) as an intercrop. This shows that one rupiah (Rp. 1.00) spent by farmers to cultivate barangan bananas will generate an income of IDR. 3.51. This means that barangan banana farming as an intercrop in oil palm PFB areas is more economically profitable than corn crops. This is because the production and selling price of barangan bananas is much higher than corn.

4. Conclusion

When implementing an intercropping system in oil palm plantations on peatlands, attention must be paid to soil acidity (pH) and fertility, the condition of groundwater levels (water management), the selection of plants, and the arrangement of plant spacing to avoid intra- and inter-specific competition. The polyculture system is 50% more profitable or half as profitable as the monoculture system.

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