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Farming Sustainability in Peatlands Following Restoration Programme in West Kalimantan

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ABSTRACT

The Indonesian government's peat restoration program, which began in 2016, is alleged to have an impact on the sustainability of peatland farming, because rewetting has the potential to cause waterlogging, limiting the crop commodities that can be cultivated. This project will look at the viability of small-scale farming on restored peatlands. To fulfill the study's objectives, we used a combination of quantitative and qualitative methods. The quantitative technique included an analysis of agricultural income to determine the economic sustainability, whereas the qualitative approach explains social sustainability. The environmental sustainability was assessed using the carbon rescue acquired after rewetting. The findings revealed that rewetting had little effect on the income from vegetable and fruit crops. The farming income, which remains relatively high, demonstrates that farming's economic sustainability is viable. Similarly, the social dimension does not detract from the sustainability aspect, because the rewetting of the land did not significantly alter the social structures and institutions that had been built in the farmer's community. Meanwhile, from an environmental standpoint, the impact of rewetting is quite favorable, as every 1 cm increase in water table level has the potential to conserve at least 0.71 tons of CO_2 per acre per year, or around IDR 13,888−26,993.

Keywords: carbon rescue, farming, peatland restoration, rewetting

INTRODUCTION

Indonesia's peatland management regulations have changed significantly during the previous five years, commencing with the launch of the peat restoration program in 2016. This strategy was implemented in response to ongoing peatland degradation, which has proven difficult to address, notably due to the frequency of peat fires during dry seasons, which result in substantial carbon emissions (Jaenicke *et al.* 2008, Khasanah & Noordwijk 2019). This approach is consistent with study findings showing that the principal driver of carbon emissions is the construction of drainage canals, which are thought to expedite peat breakdown (Ishikura *et al.* 2019). This implies that the massive construction of water channels in peatlands in the past is inextricably linked to the widespread degradation of peatlands in Indonesia. According to Mamat *et al.* (2014), this degraded peatland covers around 3.7 million ha, with Sumatra and Kalimantan having the widest areas. To address this tough state, the peatland restoration program employs three major strategies: rewetting, revegetation, and revitalization.

Peat rewetting operations are carried out by constructing canal blocks with the goal of assuring the availability of water in the channels, hence maintaining the water table level in the land region. According to the most recent research report, the existence of canal blocks up to a specific distance in land areas is very successful in raising the water table level (Gusmayanti *et al.* 2023). This strategy is designed to progressively restore peatland conditions. Next, revegetation refers to the endeavor to transplant forest flora in specific designated sites, whereas revitalization entails strengthening local farmers who may be harmed by the rewetting process. The revitalization program intends to allow farmers to continue using previously cultivated peatlands while adhering to sustainable principles, namely adapting to current conditions following rewetting. The success of revitalization is regarded as critical to the overall success of the peatland restoration program, because it is ultimately the farmers who live and work alongside the canal block infrastructure (the primary infrastructure for peat rewetting) who play a central role in sustaining restoration efforts on the ground. This indicates that local farmers will be responsible for the protection and maintenance of the canal block infrastructure. In accordance with this, developing adaptable agricultural strategies on

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peatlands is vital to maintaining the protection and sustainability of the existing infrastructure.

The successful implementation of adaptive farming practices is only possible if farmers have a thorough understanding of peatland characteristics and the importance of protecting them, as well as the ability to use peatlands in their natural state, which has undergone rewetting as they are now. This concept is based on the reality that existed prior to the restoration program, in which peatlands were managed and exploited without consideration for their inherent ecological qualities, resulting in declining productivity (Pangaribuan 2019). However, rewetting might have unforeseen consequences such as flooding or persistent waterlogging, which can result in large losses for farming firms (Arifudin *et al.* 2018). Furthermore, when peatlands have been degraded and burned, the peat surface and water table levels often fall (Afriyanti *et al.* 2021, Nusantara *et al.* 2023), making them highly susceptible to flooding during rewetting attempts. As a result, it is critical to strategically tailor the height of canal blocks and overflow structures to the unique characteristics of each peat conservation region.

In accordance with the preservation concept, the government has mandated that peatlands designated for cultivation must maintain a maximum water table level of 40 cm below the soil surface. Furthermore, the success of peatland restoration necessitates adaptive farming management, which can be achieved, among other strategies, by selecting appropriate crop commodities and implementing land-use practices that are consistent with the ecological characteristics of peatlands and the goals of their protection. Thus, the notion of biodiversity-smart farming is predicted to be achieved, in which technical or institutional options align with farmers' socioeconomic goals through conservation-oriented practices (Daum *et al.* 2023). Farmers in the research area, notably in many peat care villages in Terentang and Sungai Raya Districts, Kubu Raya Regency, have progressively come to recognize the need of peatland restoration. Currently, many forms of adaptation are being implemented based on farmers' own initiatives. For example, some farmers have begun building canal blocks called locally as *pagung* to keep water at the required level. The introduction of such techniques suggests that farmers are beginning to comprehend and accept the concept of peatland protection. Based on restoration efforts and various forms of adaptation, this study aims to quantify aspects of sustainability in terms of economic, social, and environmental dimensions, utilizing empirical data collected at both the farmer and farm levels.

Economic sustainability can be measured by the amount of direct farm revenue earned, as any conservation-oriented solution must still provide economic advantages or secure the livelihoods of farmers and their families. This theory underscores the idea of economically viable agriculture. Furthermore, such methods are projected to yield indirect economic advantages, notably in the form of ecosystem services like carbon sequestration and soil and water conservation. Meanwhile, social sustainability can be assessed by determining whether the implementation of the peat protection concept promotes broad-based engagement within farmer communities, such as by increasing participation in local groups. To examine this social dimension, farmers' engagement in organizations and various institutional characteristics that enable farming can be used as indicators.

Understanding the presence of direct and indirect economic benefits as well as social dimensions, the desired development idea has included three interrelated pillars of sustainable development: social, economic, and environmental. According to the sustainable development paradigm, development must be economically and environmentally viable, socially and environmentally acceptable, and socially and economically equitable in the sense that it can raise welfare over time. Based on these considerations, the purpose of this study is to assess the sustainability of small-scale peatland farming in regions that have been restored through rewetting.

METHODS

Research Site

This study was carried out in three villages in Kubu Raya Regency: Teluk Empening and Madusari in Terentang Subdistrict, and Limbung in Sungai Raya (Figure 1). The selection of these communities was since the peatlands in these locations have been rewetted, and local farmers have begun to incorporate peatland restoration goals into their small-scale agricultural operations.

In accordance with peatland restoration goals, farmers in the research regions have employed water table regulation to protect peat from degradation and minimize carbon emissions. One approach used is the construction of canal blocks, known locally as *pagung*, which are built along water channels ranging from tertiary canals to smaller on-farm ditches. Farmers select the spacing between *pagung* structures on their property based on their observations and practical demands to maintain ideal water table levels. According to government regulations, the water table should be kept at a maximum depth of 40 cm below the peat surface (Gusmayanti *et al.* 2023).

Data Collecting

Farmers who adopted the peatland restoration concept provided quantitative research data. Despite the modest number of farmers involved, all 34 recognized farming households participated in this study. Data from each family were collected through semi-structured interviews, with a questionnaire

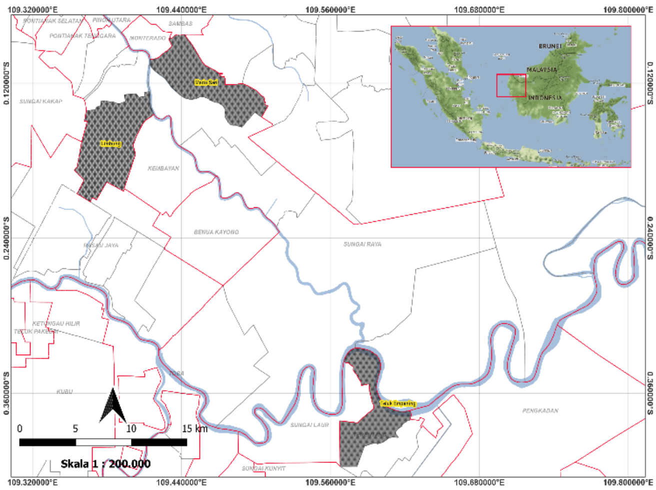

Figure 1 Study site in three village of Kubu Raya Regency

serving as a guide to guarantee uniformity in data collection. Meanwhile, qualitative data were gathered through in-depth interviews with key informants, including farmer group leaders and exemplary farmers from each village. A total of six farmers were interviewed. In addition to interviews, direct observations were conducted to document specific facts and phenomena occurring at the research sites.

Data Analyses

To determine the economic viability of small-scale farming, an income analysis was performed for each farming activity undertaken by the respondents. This research takes a basic method, estimating the difference between total revenue generated and total costs incurred during the farming process. The mathematical procedure for analyzing farming income is as follows:

$$Pd = Tp - Tb \quad (1)$$

where:
Pd = Farming income (IDR)
Tp = Total revenue [total revenue of horticulture farming (IDR)]
Tb = Total cost [total cost of horticulture farming (IDR)]

Furthermore, to establish whether the farming activity is economically profitable, a ratio analysis was performed, comparing total income to total costs. This analysis gives an indication of profitability, with a ratio larger than one indicating a lucrative farming enterprise. The profitability ratio is mathematically represented as follows:

$$R/C = Tp/Tb \quad (2)$$

where:
R/C = Ratio revenue and cost
Tp = Total revenue [total revenue of horticulture farming (IDR)
Tb = Total cost [total cost of horticulture farming (IDR)

Decision criteria:
1. If *R/C* > 1, then farming is categorized as profitable
2. If *R/C* < 1, then the farming business is categorized as experiencing a loss
3. If *R/C* = 1, then the farming business is categorized as experiencing a break-even point, not profitable and not at a loss

The next step was to analyze sustainability from a social perspective. This dimension was determined by assessing the operation of institutional factors within the farming community following the implementation of rewetting. The investigation focuses on whether the peatland rewetting program caused changes in local institutional structures. If the program is determined to weaken or corrode current institutional arrangements, it is deemed ineffective in terms of social sustainability. On the other hand, if the rewetting program does not change the current institutional characteristics, it is regarded as promoting sustainability. This can be determined by evaluating the ongoing operation of existing institutions. One important indicator is the persistence and operation of social capital across many levels of farmer activities within the community, including farming techniques, agricultural product marketing, and membership in farmer group organizations. In this context, qualitative data analysis focused on the institutionalization of norms or regulations that have a favorable impact on the sustainability of agricultural systems. These include norms governing resource exchange, profit sharing and agricultural hazards, equitable resource allocation, and meeting collective needs.

The final portion of the analysis concerns the environmental factor of sustainability. This analysis focused on the indirect advantages of peatland restoration, including carbon storage and soil and water conservation. Carbon storage was estimated using the amount of carbon sequestered, given in tons per hectare (t/ha). This amount was then converted to its equivalent in IDR (Indonesian rupiah). According to Agus (2007), the global market price for carbon credits ranged from USD 4 to USD 18 per ton. For the purposes of this study, the carbon credit price under the Reducing Emissions from Deforestation and Degradation (REDD) mechanism was assumed to be USD 5/t, or IDR 71,720/t, based on the current exchange rate (1 USD = IDR 14,344).

RESULTS AND DISCUSSION

Characteristics of Farmers and Farming

Farmers in the research area have long relied on peatland farming for their principal source of income, making these operations critical. Some peatlands have been used for food production from the initial removal of wooded areas, while others were once planted as rubber plantations before being converted to food crop land. These changes are mostly dependent on farmers' land-use decisions. For example, there has been a recent trend of turning rubber plantations into food crop fields, owing to the ongoing drop in rubber prices, which has made rubber cultivation less economically viable.

Peatlands are currently used to develop a wide range of horticultural commodities, including long beans, cucumbers, chilies, tomatoes, spring onions, sweet corn, eggplant, and bitter melon, as well as fruits such as papaya and watermelon. These crops are farmed in either monoculture systems or intercropping patterns. Furthermore, some farmers use a technique that divides a single plot into multiple smaller pieces, each planted with a different crop. Table 1 provides an overview of horticulture land use on peat soils, as well as information about the farmers who participate. More than 80% of farmers are of productive age. This age condition is significant since productive age is regarded ideal for horticulture farming, which often involves heavy labor and regular maintenance (Prayitno *et al.* 2014). However, the level of education among farmers in the study region remains relatively low. Approximately 52% have only completed elementary school, did not finish elementary school, or have never attended school. Age and education are commonly acknowledged as characteristics that influence farm productivity (Reimers & Klasen 2013, Sebrennikov *et al.* 2020). Furthermore, farmers' knowledge, particularly that acquired through various educational channels, is crucial in molding decision-making processes (Kune *et al.* 2021). Educational attainment is consequently vital in helping farmers to make decisions, such as selecting proper agricultural inputs, which can have a substantial impact on farming performance. In this context, education refers not just to conventional schooling but also to informal education, such as agricultural extension services and other non-formal learning. Nonetheless, this study focuses primarily on formal education, which, according to the data, is still very low among the farmers polled. Furthermore, based on arable land size, around 73.5% of farmers farmed land less than 0.5 ha, showing that the bulk of peatland vegetable

Table 1 Characteristics of farmers and farming on peatlands in Kubu Raya Regency

Variables	Category	Descriptive results (Farmers)	Proportion (%)
Number of samples (n)		34	
Farmers' age (yr)	< 30	3	8.82
	30–60	28	82.35
	> 60	3	8.82
Educational level	Never attended school	4	11.76
	Not graduated from elementary school	1	2.94
	Elementary school	13	38.24
	Junior high school	9	26.47
	Senior high school	7	20.59
Marital status	Married	31	91.18
	Unmarried	1	2.94
	Widowed	2	5.88
Ethnic	Javanese	26	76.47
	Madurese	7	20.59
	Malay	1	2.94
Number of dependents (people)	no	6	17.65
	1	9	26.47
	2	15	44.12
	3	4	11,76
	> 3	0	0.00
Arable land of horticultural farming (hectare)	< 0.1	8	23.53
	0.1–0.5	17	50.00
	0.51–1	7	20.59
	> 1	2	5.88

growers are small-scale. The realities of small-scale farming highlight the challenges of farm management, such as dealing with the high frequency of insect and disease infestations, weed problems, restricted access to financing, and labor shortages.

It is crucial to note that, in reaction to the risk of low income caused by commodity price changes, farmers in the study area do not rely primarily on a single source of revenue. They typically have numerous sources of income, such as coconut farms, oil palm plantations, cattle farming, or non-agricultural jobs in rural areas. As rural development progresses, this variety of revenue sources looks to become more widespread. Farmers with these qualities are subject to peatland management restrictions that must adhere to sustainable standards. As a result, the next section examines at the economic, social, and environmental aspects of sustainability, which are the primary emphasis of this research.

Sustainability of Economic Dimension

Farm income analysis is part of a study to determine the economic viability of peatland after rewetting. This approach is simply an attempt to determine the direct use value of peatland resources for agriculture. More specifically, this analysis evaluates the economic benefits of each agricultural household cultivating a plot of peatland for vegetables and/or fruit. It should be noted that because this study does not account for farmer and family labor costs, it is more correctly described as an analysis of farmer income, even though it is referred to as farm income throughout this work. Table 2 shows the entire farm revenue analysis results, which are the average amount per hectare. The average income obtained by horticultural farmers who include various vegetables (mustard greens, cucumbers, long beans, chili, tomatoes, bitter melon, and sweet corn) in one plot of land is IDR 33.06 million/ha, with an R/C ratio of 1.67. According to this finding, farmers will earn IDR 1.67 for every IDR 1 spent. This demonstrates that the farming industry is still profitable. Farming profits are defined not only by production volume, but also by the expenses that must be incurred. This analysis demonstrated that fertilizer expenses are relatively high, accounting for approximately 22.7% of overall costs. Labor expenditures are the next largest cost, accounting for around 31% of total costs. These findings are consistent with those of Putra *et al.* (2018), that significant fertilizer and labor costs in vegetable cultivation on peatlands, since horticultural farming is relatively more expensive than other crops. Furthermore, farming on peatlands incurs relatively significant agricultural lime (dolomite) costs. The lime treatment tries to lower soil acidity, which is characteristic of peatland.

The high expenses are the result of marginal land, which necessitates higher fertilizer expenditures and more rigorous maintenance to overcome numerous existing barriers. As a result, farming on peatlands necessitates a unique method tailored to their specific characteristics. According to Malta (2011), the farming methods at this research site are considered traditional because they were not fully applied using suggested technology. However, based on the revenue analysis results (Table 2), which are characterized as still profitable, the farming operation is still economically viable, or meets sustainability standards.

According to the farmers' statements, there was no difference between before and after the restoration policy, implying that peatland restoration efforts by rewetting had no substantial impact on farming activity. This suggests that canal block elevation during rewetting does not considerably impair agricultural cultivation. This suggests that the rewetting elevation is consistent with the goals of peatland protection, particularly for horticulture production. These findings are consistent with previous studies on melon cultivation in Central Kalimantan, which found that following peat restoration, the crop remained profitable. Fruit weight in melon cultivation was reported to be the same as before restoration (Antang *et al.* 2021).

Table 2 Income from various*) vegetable farming on peatlands after rewetting in Kubu Raya Regency, 2022

Description	IDR/ha
Revenue	82,061,830
Cost:	
- Seeds	1,361,366
- Fertilizer	11,108,045
- Pesticide	3,600,907
- Dolomite	1,955,556
- Stake	7,272,389
- Mulch	7,281,111
- Others (plastic strap)	518,889
- Non-family labor	15,173,333
- Depreciation of agricultural equipment	688,645
Total cost	49,000,241
Farming income	33,061,589
R/C (revenue/cost)	1.67

Remarks: *) A combination of several commodities, such as mustard greens, cucumbers, long beans, chili, tomatoes, bitter melon, sweet corn in one farming unit.

Sustainability of Social Dimension

As previously stated, this sustainability category reflects the triple bottom line concept, which emphasizes sustainability in three areas: economic (profit), social (people), and environmental (planet). A sustainable business focuses not only on raising revenues, but also on improving community well-being and making a beneficial impact on the environment. When evaluating social implications, it is critical to include the level of community well-being. Conceptually, this can be evaluated by assessing the continued operation of various institutional characteristics within the farmer community. The operation of these institutional characteristics also demonstrates the continuity of farmer engagement or at least shows that no significant changes have happened.

The presence of social capital in agricultural connections can reveal institutional elements within farmer communities. The research site discovered characteristics of social capital in farming activities, agricultural product marketing, and within farmer organizations, such as farmer groups. Table 3 summarizes how social capital continues to function within the farmer community at the research location. The most visible type of social capital at the farm level is the exchange of labor between farmer households. This practice is common in farmer communities in West Kalimantan and throughout Indonesia, where social ties between farmers are strong. This labor exchange method is widely used as a solution to address labor shortages in rural areas and reduce agricultural production costs. Furthermore, this technique helps farmers enhance their relationships. According to Subejo (2009), such labor exchanges are classified as rigorous and type of reciprocity.

Furthermore, when it comes to the institutional side of agricultural marketing, farmers and agricultural product collectors (middlemen) have a strong local institutional link. This connection mechanism seeks to promote farming and typically includes broad elements such as farming financing, the supply of agricultural production facilities, and agricultural product marketing activities. This system is believed to be extremely involved, with the goal of sharing risks and advantages between both parties for this institution to assist overall farming activities (Sandika 2011, Ferrol-Schulte *et al.* 2014, Sudrajat *et al.* 2015, Abebe *et al.* 2016).

Finally, at the farmer group level, typical kinds of engagement remain prevalent, such as the maintenance or cleaning of water channels. This study found that farmer engagement within current farmer organizations remains reasonably high, particularly in the maintenance of tertiary channels, which is the farmer's obligation. This demonstrates that current social structures have not experienced considerable modifications, therefore farmer participation can likewise be classified as functioning well. farming activities inside their organizations are regarded as critical for improving income distribution and wellbeing, as these groups serve as both sources of information and routes for obtaining resources through linkages with institutions outside the farming community. Farmer associations, for example, assist in facilitating access to fertilizer distribution and various government subsidies, lending from rural financial institutions, and other critical resources such as agricultural science and technology that promote successful farming.

Sustainability of the Environmental Dimension

The average carbon storage capacity and soil and water conservation in this study indicate the environmental sustainability element, indicating that rewetting has a good influence. The findings of a survey of the recovered peat thickness yielded data ranging from 1 m to 3 m, with an average of 1.5 m. Then, if rewetting reduces carbon emissions, carbon reserves can be computed. According to Maswar's (2011) research, carbon stocks in drained peatlands range from 622.24 to 3,105.08 t C/ha. Variations result from variances in land location, carbon density, and peat thickness. In some areas, the carbon concentration might be considerably higher; for

Table 3 Social capital in farming activities on peatlands after rewetting in Kubu Raya Regency

Level of activity	Type of activity	Form of social capital	Element of social capital	Benefit
On farm	Labor exchange among farmer's households	Labor exchange	Norm of reciprocity	- Fulfilled workforce needs - Reducing farming costs
Marketing of agricultural products	Sales of production through middlemen	Sharing risks and profits	Network; norm of reciprocity	- Well-functioning sales - Reduced risk
Farmer group	Distribution of fertilizer from the government	Equal distribution	Network; norm; mutual trust	- Fulfilled fertilizer needs
	Participation in farmer group activities, for examples; cleaning tertiary canals and member meetings	Fulfillment of shared needs	Network; norm; mutual trust	- Fulfillment of drainage needs

example, according to the findings of Maizaldi *et al.* (2019) that the level can reach 19,973.27 t C/ha.

Referring to Maswar (2011)'s research results, which are stated to be similar to the case of this study, and then defining the following assumptions: (a) bulk density of around 0.1 g/cm^3, and (b) organic carbon content of peat of 50%, peat with a depth of 1 m is estimated to be able to store 500 t C/ha. If the average peat depth at the study site is 1.5 m, the area's carbon storage is projected to be 750 t/ha. Furthermore, if the stored carbon is sold for IDR 71,720/t, or $5/t, it is expected to produce at least IDR 53.79 million/ha in carbon revenue. These findings highlight the necessity of rewetting efforts in peatland restoration, as carbon trapped in peat has the potential to be released into the atmosphere as emissions due to organic matter breakdown.

Water table level is a major measure of carbon emissions in peatlands. According to published equations, a 1 cm increase in water table level through rewetting reduces CO_2 emissions by 0.71−1.38 t/ha per year or 0.19−0.38 t C/ha per year (Hooijer *et al.* 2010, Agus *et al.* 2013, Carlson *et al.* 2015). This reduction corresponds to a monetary value of roughly IDR 3,888−26,993/ha each year. Thus, it may be claimed that peatland farmers that implement restoration projects not only benefit directly from agricultural activities, but also indirectly contribute to carbon storage, which has a considerable economic value within their farming practices.

Another significant advantage is soil and water conservation. In this regard, assuming an 85% peat soil porosity, a peatland with a depth of 1 m and a water table maintained at 0.4 m (as proposed by the government in Government Regulation No. 57 of 2016), is expected to hold more than 7,000 m^3 of water/ha. Meanwhile, with an average peat depth of 1.5 m, it is expected to contain water reserves of approximately 10,500 m^3/ha. Furthermore, assuming the cost of water for agriculture is only IDR 500/m^3, the economic value of water in this peatland is at least IDR 5.25 million/ha. Based on these findings, Table 4 summarizes the indirect benefits of rewetting, suggesting that farming on rewetted peatlands promotes environmental sustainability, owing to the comparatively significant indirect benefits of carbon storage and soil and water conservation. The indirect benefits are more valuable than the direct gains.

Table 4 Indirect benefits obtained from agricultural land after rewetting in Kubu Raya Regency, 2022

Description	Benefit value (IDR/ha)
Carbon storage	53,790,000
Water reserve conservation	5,250,000
Total revenue assumptions	59,040,000

CONCLUSION

Peatland farming is currently on track to meet the triple bottom line philosophy (profit, people, and the environment). In this setting, peatland restoration appears to have improved the sustainability of small-scale farming. The peatland restoration program has a good impact since the practice of rewetting, as a restoration strategy, may still be successfully applied by small-scale farmers. This suggests that rewetting operations do not jeopardize crop production, particularly in horticulture.

Horticultural farming's ongoing high profitability reflects the sustainability dimension as well. Similarly, farmer engagement in groups and community activities has remained virtually unchanged, demonstrating that existing institutions continue to play an important role in promoting social sustainability. Furthermore, rewetting has a favorable environmental impact by creating indirect advantages such as carbon storage and soil and water conservation. Based on an analogy with the literature review and assumptions about the peatland conditions at the research site, an analysis of the organic carbon reserves that can be stored is estimated to be at least 750 t C/ha, or IDR 53.79 million/ha. Overall, the findings of this study demonstrate that the restoration effort has resulted in better circumstances for sustainable farming than in the pre-program period.

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