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Original Research Article

Agroforestry on peatland: Livelihood options for community resilience to climate change adaptation

Ary Widiyanto[1,*], Sanudin[1], Aditya Hani[2]

[1] *Research Center for Population, National Research and Innovation Agency, Jakarta 12720, Indonesia. E-mail: aryw002@brin.go.id*

[2] *Research Center for Ecology and Ethnobotany, National Research and Innovation Agency, Bogor 16911, Indonesia.*

ABSTRACT

The effects of climate change are already being felt, including the failure to harvest several agricultural products. On the other hand, peatland requires good management because it is a high carbon store and is vulnerable as a contributor to high emissions if it catches fire. This study aims to determine the potential for livelihood options through land management with an agroforestry pattern in peatlands. The methods used are field observation and in-depth interviews. The research location is in Kuburaya Regency, West Kalimantan, Indonesia. Several land use scenarios are presented using additional secondary data. The results show that agroforestry provides more livelihood options than monoculture farming or wood. The economic contribution is very important so that people reduce slash-and-burn activities that can increase carbon emissions and threaten the sustainability of peatland.

Keywords: Agroforestry; Peatland Management; Livelihood Options; Community Resilience

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1. Introduction

The phenomenon of climate change is not new to Earth's history. The same history demonstrates the subsequent effects and complete record of climatic changes on the earth's surface and the existence and growth of all living things, including humans, animals, and plants[1]. It affects many systems and sectors that depend on climate, including water resources, terrestrial and marine ecosystems, food production, natural disasters, coastal zones, industry, and human health. Climate change is a fundamental alteration in the physical processes of the Earth. The acceleration of climate change in the final decades of the twentieth century appears to be the cause of these impacts. In the Arctic, where there has been the greatest increase in atmospheric temperature, sea ice and permafrost areas have drastically decreased. The poles and higher altitudes of mountains are home to many species and habitats[2]. Thus, it is incumbent upon the scientific community to develop and refine effective methods of assessing the impacts of climatic variations on society[3].

Peatlands are special habitats that comprise about 3% of the earth's surface and are distinguished by a high sensitivity to climatic changes. These extremely complex ecosystems impact the local and global water and carbon cycle[4]. Indonesia has the 4th largest peat ecosystem in the world and the largest tropical peat ecosystem in Indonesia. Indonesia's peat ecosystems reach 24.7 million hectares in 865 Peat Hydrological Areas (KHG). Peatland Indonesia can store up to 46 gigatons of carbon, meaning that 8%–14% of the carbon is in peatlands, and the majority are located on the three major islands: Sumatra, Kalimantan, and Papua[5]. The huge peat potential must be managed to provide added value without destroying the natural function of the peatland itself. Peat management that harmonizes economic and ecological functions will positively impact environmental development[6].

The use of peatlands for agriculture in Indonesia began with the success of indigenous peoples who saw peatlands as a source for producing traditional food crops, fruits, and spices, then grew into large plantations managed modern to obtain better incomes, such as palm oil plantations. However, this must be done sustainably because unsustainable use of peat causes damage to peatlands[7].

In West Kalimantan Province, the existing condition of the peatland area is 1.68 million ha (11.4% of the province's area). The largest peatlands are in Kubu Raya Regency, 471,187 ha (28.0%), followed by Ketapang Regency, 284,506 ha (16.9%), Kapuas Hulu, 282,832 ha (16.8%) and Landak Regency 56,203 ha (3.3%)[8]. The distribution of these peatlands causes West Kalimantan Province to be one of the provinces prone to fires. Peatland fires in West Kalimantan occurred many years ago. Until now, these fires still occur frequently in every dry season. Many factors influence land fires that cause haze disasters. Fires are caused by two main factors: climatic conditions and human activities in land management. Fires are caused by human activities as much as 99%, either intentionally or due to elements of negligence. These include land conversion activities 34%, illegal cultivation 25%, agriculture 17%, social jealousy 14% and transmigration projects 8%. Land fires due to climate influences only occur in a small number[9].

Peat and Mangrove Restoration Agency of Indonesia[10] noted that around 2.5 million hectares of peatland were damaged and needed immediate restoration. The damage to peatlands has led to increased ecological disasters such as floods and haze due to peatland fires. Rehabilitation is the keyword of the thesis that many peat swamp experts have put forward to be able to restore damaged peatlands to their original state or function[11]. Wibisono *et al.*[12] recommend replanting (reforestation) with species suitable for peat lands that are already exposed, both on land with peat depths of less than three meters or more.

Paludiculture is an alternative peat restoration technique in the form of fishery with plant cultivation in wet peat swamp land[13]. This peat restoration technique is believed to reshape ecological functions and biophysical conditions and restore the economic functions of peat ecosystems[14]. One technique that can be developed in paludiculture is agroforestry. Agroforestry can maintain ecological, social, and economic functions. However, agroforestry-based peatland rehabilitation is still a rare effort, both in terms of the program and its success, so this activity is carried out to implement agroforestry patterns through agroforestry on peatlands.

The agroforestry system is expected to solve social and environmental issues such as poverty, global warming, environmental degradation, food scarcity, shelter, energy, and water[15]. Moreover, Dohong *et al.*[16] said that the causes of peatland degradation are related to livelihoods. Thus, restoration efforts must be focused on finding alternative livelihoods. This study aims to determine the livelihood sources of the people in peatland and to offer agroforestry as a better system than monoculture farming from an economic and environmental standpoint.

2. Methodology

This research was conducted in 2017 and 2018 in Rasau Jaya II Village, Rasau Jaya District, Kubu Raya Regency, West Kalimantan Province (**Figure 1**). The village of Rasau Jaya II is included in the Peat Hydrological Unit of the Punggur Besar River and Kapuas River. The choice of location was based on the consideration that West Kalimantan Province is one of the priority provinces for peat restoration besides Riau, Jambi, South Sumatra, Central Kalimantan, South Kalimantan, and Papua Province. Kubu Raya Regency is the youngest district in West Kalimantan Province[17] but has the largest peatland area in West Kalimantan Province[8]. The Peatland area in Kubu Raya Regency is about 471,187 ha or 28% of the total peatland area in West Kalimantan[8].

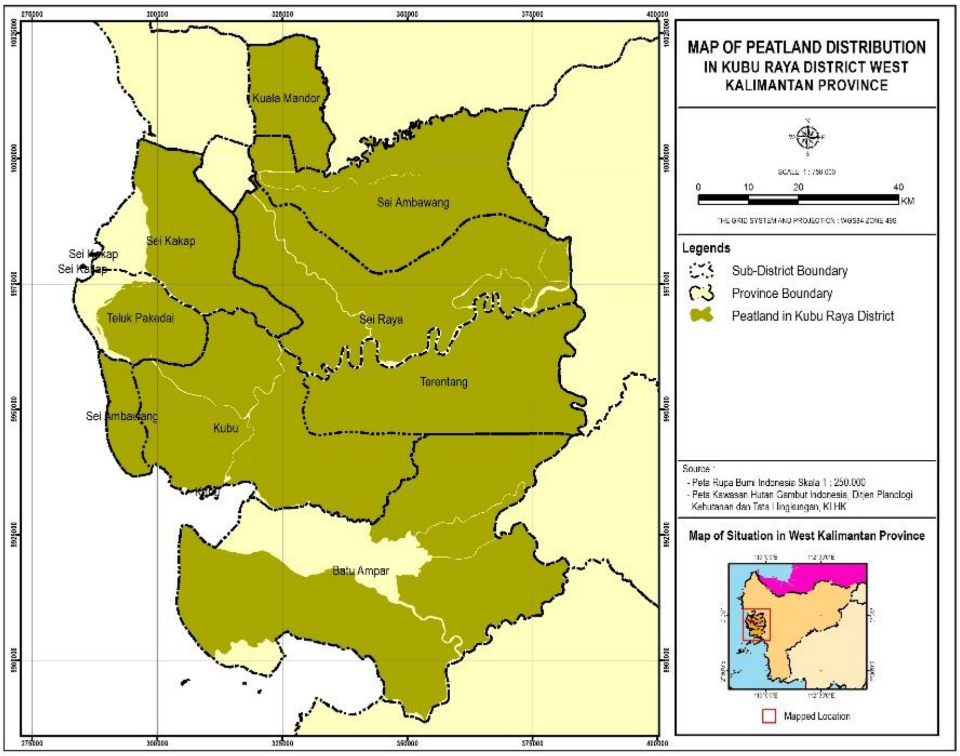

Figure 1. Research location[18].

Data collection was carried out through observation and interview methods. Data analysis was carried out descriptively for data on land use and farmer income from monoculture farming activities. This data is then combined with secondary data regarding the woody plants suitable for growing in the peatland area. Furthermore, calculations are carried out to determine the most profitable tree species if planted in an agroforestry pattern with annual crops. This calculation considers the price (return), first harvest time, initial cost to build, ideal spacing, and environmental impact. Of the seven recommended tree species, a score of 1 (lowest) to 7 (highest) was made based on various research results conducted before and the results of interviews with the community. The explanation of each variable is as follows:

1) Price (return): the economic value of the seven types of wood that have the potential to be developed in peatland, according to the results of Wiesen, 2014. The higher the return of value, the higher the score.
2) Time of first harvest: This is the age of the plant until the first harvest is carried out. The faster the harvest, the higher the score.
3) Initial costs to build: Costs required for land preparation, procurement of seeds, and planting. This stage depends on the type of plant. Some require full land clearing, and some do not. The lower the initial cost, the higher the score.
4) Plant spacing: Indicates the ideal spacing for plants to grow well. The greater the spacing, the higher the score. This spacing is related to the greater space available for crops.

Next, to compare three types of land use patterns, namely monoculture farming, monoculture wood, and agroforestry, we used a score of 1 (lowest) to 3 (highest). The explanation of each variable is as follows:

1) Income: the higher the value, the higher the score.
2) The number of sources of income: the

more the number, the higher the score.

3. Results

The results of the analysis show that the main occupation of the people in the villages of Rasau Jaya II and I is farming on their land. In general, women work as agricultural laborers in the fields during the planting and harvest seasons and in the garden during planting, fertilizing, and weeding activities. Most of the respondents in both Rasau Jaya II and I manage wetlands (peat). Land preparation is done by slashing, burning peat land, and planting. The main commodities planted by the community in Rasau Jaya II Village are corn and peanuts, while in Rasau Jaya I Village, they are sweet corn, peanuts, chillies, tomatoes, long beans, corn, pumpkin, and watermelon. Community preference regarding trees and crops in these villages can be seen in **Table 1**. Factors that influence socio-economic conditions in the two villages are the interaction between the community and extension workers in peat management and work ethic (motivation).

Table 1. Community preference for trees and crops in the research location.

Trees	Crops	MPTS/NTFPs
Pulai (Alstonia pneumatophora), and Gerunggang (*Cratoxylum glaucum* Korth) Can grow well in peatland	Corn, chilli, ginger, tubers, cabbage, tomato, corn, beans, pineapple, long bean, and watermelon, easy to grow, has a stable selling price, and has a short harvesting period (4 months)	Jelutung rawa (*Dyera polyphylla*)

Remark: MPTS/NTFPs = Muti purposes tree species/non-timber forest products.

3.1 Monoculture farming

Monoculture farming was the community's main livelihood source when this research was carried out. In general, farmers practice monoculture cultivation. Annual plant planting activities were carried out around October 2017, and around March and April 2018, the yields for these plants were obtained. Plant productivity, product selling prices, and income received by the community can be seen in **Table 2**.

Table 2. The most widely cultivated crops by the community.

Commodity	Productivity (kg/ha)	Price (IDR)	Total income (IDR/ha)
Peanut	1,100	14,000	15,400,000
Corn with cob	2,650	2,500	6,625,000
Peeled corn	1,833	10,000	18,833,000
Chilli	1,300	15,000	19,500,000
Tomato	5,900	3,000	17,700,000
Bitter gourd	2,200	1,500	3,300,000
Eegplant	3,000	8,000	24,000,000

Remark: 1 USD = +/− 15,000 IDR.

Data shows that eggplant is a type with high productivity and contributes the highest income compared to other types. Tomatoes also have the highest productivity. Even so, the people in those places mostly grow sweet corn. Sweet corn is the most widely planted because it is easy to manage and does not require a lot of processing like shelled corn or other types. Corn is the plant most preferred by the community because, apart from its relatively stable price, it also takes a short time to harvest and is easy to manage. Cultivated by farmers with an average land area of >1 ha and farmers with capital.

Even though it looks profitable, there are several main drawbacks of the monoculture farming system, especially in the research location, including 1) monoculture farming is vulnerable to reduced product prices during the main harvest, which generally takes place simultaneously; 2) it more susceptible to attack by pests and diseases; 3) harvesting can only be done once a year, meaning that farmers have to repeat the cultivation process from the beginning the following year; 4) for the next year's planting process it is generally done by burning the land, which is considered much faster and cheaper even though the slash and burn process is very harmful to the environment.

3.2 Potential commodity for agroforestry development

Peatland can be utilized based on its depth: shallow peat (0–2 m) with seasonal plant species such as rice, corn, vegetables, beans, and tubers. In comparison, deep peatlands (2–3 m) can be used to develop plantation crops such as rubber, oil palm, coffee, cocoa, and sago[19]. The agroforestry pattern accommodates both types of plants through a combination of planting and spacing. According to Wiesen in Balai Penelitian dan Pengembangan Agroforestry[20], there are several Muti Purposes Tree Species (MPTS) and Non-Timber Forest Products (NTFPs) types of plants that have high economic value, as shown in **Figure 2**.

To get a more detailed picture of the seven types: Sago, Rubber, Gelam, Jelutung, Illipe Nut, Oil Palm, and Candle Nut, we added information about time first to harvest, productivity, price per unit, and spacing. Briefly, this can be seen in **Table 3**.

From the results of **Table 3** and **Figure 2**, we create opportunities for developing agroforestry in peatland based on timber plantations as a medium-long-term source of income for the community. This calculation considers the price (return), first harvest time, initial cost to build, ideal spacing, and environmental impact. Environmental factors are considered the same because all types of these plants require eradication of pests and diseases and fertilization. Furthermore, according to product prices, the 1st harvesting time, the initial cost, crop spacing distance, and ease of maintenance, we calculate the superior commodities on peatland to get the most recommended commodity (**Table 4**).

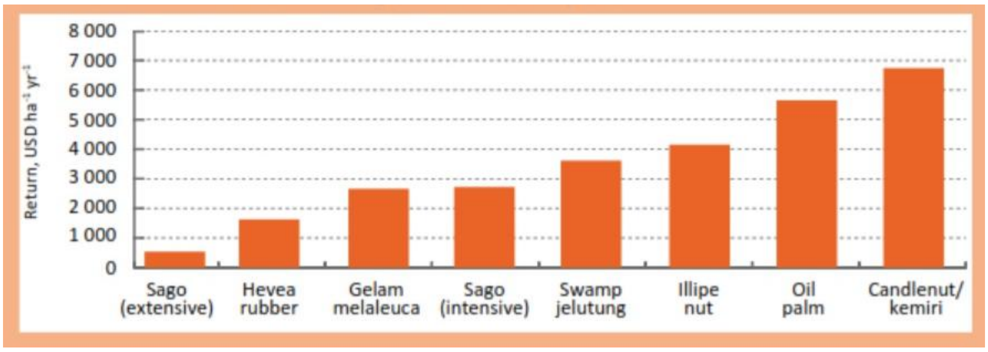

Figure 2. Some potential plants in peatland in Balai Penelitian dan Pengembangan Agroforestry[20].

Table 3. Important information on high economic value commodities in peatland.

	Sago	Rubber	Gelam	Jelutung	Illipe nut	Oil palm	Candle nut
1st harvested (year)	6–7	5	7 months	7	8–9	4	2
Productivity	40–60 ton/ha	1 ton/ha	18 ton/ha	30 kg/tree/day	250–800 kg/tree/year	25–30 ton/ha	3–4 ton/ha
Price (IDR/kg)	1,000	13,000	295,000 (cajuput oil)	30,000	1,500	2,500	850,000 (dry)
Spacing	8 m × 8 m	6 m × 3 m	1 m × 1 m	5 m × 5 m	5 m × 5 m	7 m × 7 m	9 m × 9 m

Source: It's sourced from the references [21–28].

Table 4. Scoring results for seven superior peatland commodities.

Commodity	Price	1st harvested year	1st initial cost	Space for crops (canopy and spacing)	Maintenance
Rubber	1	4	2	4	6
Gelam	2	7	7	1	4
Sago (intensive)	3	3	3	6	5
Jelutung	4	2	6	2	2
Illipe nut	5	1	5	3	1
Oil palm	6	5	1	5	7
Candle nut	7	6	4	7	3

The analysis shows candle nut has many advantages compared to the other six products. Candle nut is harvested quickly, has high economic value, and has a spacing that allows it to be developed for agroforestry patterns. In addition, candle nuts do not require maintenance compared to other types, and the initial planting costs are not too high. On the other hand, illipe nut is the last choice, especially because the first harvest time is very long.

The advantage of plants introduced from dry land agroforestry is that they reduce the risk of slash-and-burn practices because the plants chosen are not annual plants. Farmers will lose if they still practice slash and burn. However, the most important thing to note is that not all types of plants above are suitable for cultivation in peatland. For this reason, it is necessary to pay attention to special studies related to environmental impacts before practicing agroforestry with these types of plants.

Rubber plants are a type of latex producer originating from South America, Asia, and South Africa, which were brought to Indonesia by the Dutch colonial government in 1864[29]. The area of smallholder rubber plantations in 2021 will be 3.4 million ha, while those cultivated by the company will be 354,400 ha[30]. Rubber is a plant that can adapt well to peatlands[31]. People's rubber plantations in South Sumatra contribute up to 60% to farmers' income[32]. Gelam is a type of plant native to peat swamp areas that has high economic potential as a building material which has properties that improve when submerged in water and as a basic ingredient for traditional medicine. Gelam is a pioneer species that grows after fires occur in peatlands[28].

Indonesia has the largest area of sago plantations in the world, with a sago area of 206,150 ha[33]. Sago plants aged two years can be used for fronds as fences, leaves for roofs, bark and stems as fuel, stem parts as food and animal feed, or processed into biofuel[34]. Swamp Jelutung has high adaptability to peatlands and has higher financial viability if cultivated using agroforestry methods than monoculture patterns[35]. Jelutung is widely used as a peatland rehabilitation plant[36]. People traditionally use Jelutung sap as a commodity, as medicine for swelling, wounds, and toothache, and as a honeybee nest[37].

Illipe nuts are produced from 13 types of trees from the Dipterocarpaceae family, which have high value and are an export commodity as raw material for vegetable fats, the cosmetics industry, and as a substitute for cocoa butter spread across Kalimantan and Sumatra[38]. Several types of illipe nut producers that can grow in shallow peat are Shorea *hemsleyana*, S. *macrantha* Brandis, S. *macrophylla*, S. *pinangan*, S. *palmbanica*, S. *seminist*, S. *mecistopteryx*, and S. *beccariana*[39].

Indonesia is the country with the largest palm oil plantations in the world. In 2019, the area of oil palm plantations was 14.45 million ha, consisting of large company milk plantations and smallholder plantations[40]. The development of oil palm on peatlands considers factors: a) water management, b) land fires, c) drought, d) use of ameliorant materials, and e) application of location-specific technology[41]. Oil palms planted on peat need water management to dispose of excess water in the rainy season and conserve water in the dry season[42]. Candlenut is a type of fruit that is usually used as a food ingredient. People in Jambi prefer planting their peatlands with candlenuts because they are considered to have high economic value[43]. Sunan candlenut is a type that is suitable for reforestation on marginal land from the lowlands to 1,000 m above sea level. The candlenut seeds can be used for their oil content for various purposes and biodiesel[40].

3.3 Agroforestry as a solution

Next, we compare three types of land use patterns, namely monoculture farming, monoculture wood, and agroforestry, especially from carbon stocks, the time of obtaining income, and the number of sources of income (**Table 5**).

Table 5 shows that agroforestry has advantages in terms of medium-long-term income and alternatives to more than one source of income. Monoculture farming has an advantage in terms of short-term income. This fact makes it difficult for farmers to switch from monoculture farming because they are generally subsistence farmers, most of whose income is used to meet basic needs. The main thing to highlight here is that agroforestry offers multiple livelihood options (**Table 6**).

Table 5. Scoring results for three land use patterns.

Variable	Monoculture agriculture	Monoculture wood	Agroforestry
Short-term income	3	1	2
Mid-term income	1	2	3
Long-term income	1	2	3
>1 source of income	1	2	3
Total	6	7	11

Table 6. Livelihood options in agroforestry system compared to monoculture farming.

Monoculture agriculture	Agroforestry
One primary income at the time of harvesting undergrowth.	More than one type of income: Crops, MPTs, timber, and other types according to the type of agroforestry being developed.
Additional jobs from the agricultural sector are limited.	On-farm additional jobs are more varied, for example, as a resin tapper for Jelutung wood.
Women work as agricultural labourers during the planting and harvest seasons and in the garden during planting, fertilizing and weeding activities.	Apart from this, women can also process or market non-timber forest products or MPTs.
1 product is more susceptible to price changes, especially during the harvest season.	Many products mean many alternative sources of income that become income reserves.

4. Discussion

It has a fascinating long history that local communities have used peatlands for agriculture intending to maintain life. Farmers who work on peatlands have unique skills and knowledge in managing peatlands. The government then planned to open peatlands based on this knowledge and indigenous wisdom, particularly in favour of transmigration initiatives from Java, Nusa Tenggara, and Bali. However, using peatlands for agriculture has altered their fertility and has reportedly caused land degradation, necessitating improvement measures[44].

Peatland restoration efforts will be aided by rewetting the area and replanting native peat plants or species that can withstand flooding or wet conditions. Rewetting dry peatlands is necessary for the use of paludiculture in real life. The rehabilitation of degraded peatlands is supported by initiatives in this direction[45]. Paludiculture-based agroforestry techniques can therefore be used as an alternative to peat farming. The forest trees planted as part of the agroforestry system will not only have economic advantages but also serve to control water on peatlands.

Agroforestry in peatland is also not new because it has been practiced in other areas. For example, Rotinsulu *et al*.[46] said six agroforestry systems were found in various peat depths in Central Kalimantan. Farmers cultivate vegetable and fruit-based agroforestry on shallow peat, annual crops and fruit on medium peat, and fruit and rubber-based agroforestry on deep peat. Most farmers grew endemic plants, including Gerunggang (*Cratoxylum arborescens*), Gelam (*Melaleuca leucadendra*), and Rubber (*Hevea braziliensis*). The study's findings can be used to develop a peatland rehabilitation strategy because they are compatible with the sociocultural norms of the area and flexible enough to consider both conservation and economic concerns.

Also, in Central Kalimantan, Jaya *et al*.[47] reported that farmers applied agroforestry cultivated land by combining Jelutung (*Dyera costulata*) with many commercial plants with a 3 m × 6 m spacing. The crops cultivated with Jelutung included luffa

(*Luffa acutangula*), bitter gourd (*Momordica charantia*), leek (*Allium ampeloprasum*), and chili (*Capsicum annuum*). The average income per planting period ranges from IDR 8,050,000 to IDR 192,500,000 for a 10,000 m^2 planting area (USD 1 = IDR 15,000). The best income and cost ratio (R/C) is bitter gourd farming, with a value of 7, eggplant, luffa, and waxy corn, with a value of 3, while the smallest is leek, with a value of 2. Some farmers can develop their agriculture through planting areas or agricultural varieties.

Because of its propensity to flourish in peatlands, Liberica coffee (*Coffea liberica*) is called a peat coffee plant. Agroforestry techniques have been used in several places to grow Liberica coffee, including coffee with betel nuts and coconuts (in Tanjung Jabung Barat Regency), rubber and coffee (in Ogan Komering Hilir Regency), rubber, betel nuts, and coconuts (in the Meranti Islands), and Liberica coffee agroforestry-based practices in Central Kalimantan[48–50].

The agroforestry of Jelutung, palm oil, betel nut, coconut, and pineapple generates related economic value and additional diversified revenue. Because oil palm plantations help the local economy, farmers are more inclined to establish them. Because farmers produce betel nut plants by hand, they are inexpensive. Due to the variable cost of labor in the logging industry, Jelutung has the greatest production expenses and, as a result, earns less than palm oil, coconut, and betel nut[51,52].

According to Annisa *et al*.[53], agroforestry has the potential to significantly improve environmental preservation, climate change mitigation, and food security. Due to the need for control materials during the peat stabilization process to maintain the elemental composition, carboxyl (COOH), and OH-phenol functional groups so that the peat conditions become stable, some research findings indicate that agroforestry systems can be an effective buffer in peatlands for fire control. Moreover, Lestari *et al*.[54] said that increased CO_2 absorption could improve photosynthetic efficiency and oxygen production in forest plants and seasonal crops. These procedures boost biomass production, which helps to preserve soil organic matter and avoid erosion. Organic matter improves the ability for water retention and rewetting.

Additionally, this system has an impact on the microclimate. For instance, because the vegetation above it provides shade, the soil becomes more humid, resulting in a decrease in temperature and an increase in air moisture. Indirectly, agroforestry can maintain groundwater levels and decrease excessive evaporation, especially during the dry season.

However, Wahyunto *et al*.[55] suggested that it should be careful not to overgraze the agricultural production and conversion-producing forest regions with peatland plantation and agricultural development. Cultivating about 10% of uncultivated log-over forests and shrubs is possible. Given their poor inherent soil fertility and significant potential greenhouse gas emissions, peat soils with a thickness of more than 3 m should be set aside for conservation or forest protection if used for agriculture.

Lastly, we must consider the market of some specific product. The community created an agroforestry system to promote peatland restoration while having a source of income. Unfortunately, there isn't a market for a certain product right now. Other crops will also become less profitable because their prices will fall during harvest. As a result, product diversity is required as a community-wide solution. Future peatland plant developments must access potential markets to benefit the neighborhood and raise human well-being[56].

5. Conclusion

Facing climate change, it is very important to keep the peatland area maintained and avoid land burning, which can increase carbon emissions. Based on research, agroforestry can be used as an alternative for managing peatland because combining crops with MPTS and trees can prevent farmers from burning their crops. In addition, agroforestry also offers more alternative livelihood options, thereby increasing community resilience in dealing with the impacts of climate change. Enrichment of woody plant species in monoculture farming activities can increase above-ground carbon stocks, increasing the total carbon stock in the area. Peatland with a 0–2 m depth is the most suitable for this activity. The choice of a combination of plant species is the key to the success of agroforestry on peatlands. Although several types of trees have high economic value, not all are suitable for use in agroforestry patterns because of the spacing and width of the canopy of these types of plants. The selection of tree species must also consider several factors, such as the time of first harvest, which is very important for farmers' income, initial costs, maintenance costs, and the impact on the environment related to soil cultivation and native species.

Author contributions

Conceptualization, AW; methodology, S; validation, S; formal analysis, AH; resources, AW, S and AH; writing—original draft preparation, AW, S and AH; writing—review and editing, AW; visualization, AH; supervision, S. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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