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Developing sustainable and profitable solutions for peatland restoration

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Developing sustainable and profitable solutions for peatland restoration

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Abstract. Over the past decades, a large area of peat swamp forests in Indonesia has been cleared of the original forest cover and developed as agricultural lands. Several important issues are associated with the clearing and drainage of peat forest areas, including loss of biodiversity, increased emission of Green House Gases (GHGs), and smoke/haze pollution. Moreover, the development of large-scale oil palm plantations did not always improve local livelihoods. We describe how the restoration of degraded peat areas through paludiculture and inclusive value chains development could result in sustainable livelihoods and climate-resilient peat areas in Indonesia. We illustrate this by describing business cases of seven valuable native peat swamp forest species which could provide income for local forest communities. An analysis of the sago value chain shows that sago cultivation has a positive contribution in providing economic benefits to all actors, including local farmers, although improvements could be made for better value sharing. Paludiculture has important environmental benefits in comparison to existing drainage-based peat cultivation systems. The combination of environmental and economic benefits is an important incentive to develop the paludiculture system further to improve current peat management systems and assist further peat restoration in Indonesia. The development and implementation of paludiculture systems, particularly species selection, should have more community participation to ensure the sustainable restoration of degraded peat areas.

1. Introduction

Tropical peat swamp forests are complex and unique ecosystems, rich in biodiversity and carbon [1], [2]. They have developed over the last thousands of years by the accumulation of organic matter in acid, water-logged conditions. Indonesia harbors a large part of the world's tropical peatlands with an estimated area of about 15 Mha [3]. Most of those peatlands are naturally covered by various types of tropical peat swamp forests, unique ecosystems with many specialized and endemic species [4]. However, over the past decades, a large area of these peat swamp forests have been cleared for their timber and consecutively drained and developed to cultivate palm oil and other agricultural crops [5-7]. This has caused severe problems like huge carbon emissions, peat subsidence and compaction, large peat fires and associated haze and smoke problems, as well as loss of unique ecosystems and associated biodiversity [5, 8, 9]. In addition, large areas of cleared peat swamp forest are lying idle for various reasons, including mismanagement and land speculations. Local communities in these areas are often struggling for their livelihoods with high levels of poverty and unemployment [10, 11]. These drained and degraded areas are often covered by a dense cover of herbs, ferns and grasses, often induced by regular burning [12-14].

Over the past decade, paludiculture has been promoted as a promising approach to rehabilitate degraded peatlands by providing an income to local farmers and reducing the negative environmental impacts of drained peatland systems (e.g. [15, 16]). Paludiculture (from Latin palus 'swamp and culture 'cultivation') is a wetland agricultural system that produces agricultural crops and/or biomass from wet and rewetted peatlands while maintaining the peatland's natural conditions [17]. Besides contributing to peat soil conservation, rewetting peat also reduces GHG emissions and the risk of peat fires. Paludiculture also provides income to local communities through food crops, timber, and non-timber forest products (NTFP). Grown in mixed systems, it also may contribute to a more biodiverse environment [18].

[16] describes the biophysical requirements of paludiculture systems for peat areas in Kalimantan and Sumatra and shows that sustainable production on degraded peatlands can be achieved by rewetting and planting with the right combination of suitable crops and tree species. Middelberg et al. [19] indicate that paludiculture systems can provide more income and have less detrimental environmental effects than traditional oil palm plantations on drained peat. They also report that many Malaysian stakeholders (including oil palm growing farmers) are aware of the environmental issues of growing agricultural crops on drained peatlands. They also indicate that there is a lack of knowledge on the cultivation, processing and value chains of non-drainage peatland species. They recommend further testing of paludiculture species and cultivation systems (e.g., intercropping) as well as the development of improved value chains and new markets for paludiculture products [19].

This is confirmed by [20], who indicate that ecological knowledge on suitable species and methods to implement for alternative (wet) peat cultivation are still largely lacking, especially in its applied use. Therefore, it is important to develop holistic alternative management systems on peatland to minimize degradation and optimize production.

It is also important to involve a wide range of stakeholders in further development and implementation of peat restoration initiatives, ranging from local communities, government bodies, private industry and NGOs. Only by involving these groups meaning full and sustainable achievement can be made. In a series of seminars on "Peatland management and wet livelihood opportunities in Indonesia" (organized by FAO, UNEP and various other partners) at the beginning of 2021, several examples for "wet livelihoods" were given. Commodities produced in these remote peatland areas go through a complex series of stakeholders and channels before making their way to the domestic and international markets. Stakeholders within these commodity chains have to work with changing consumer demands, markets and certification regulations, technological advancements, and an increasing number of national and international laws and regulations. The analysis of the different stages of a value chain, from harvest via processing to consumption, can help develop sustainable innovations so that markets for products are developed, and better value shares are guaranteed for the local producers.

In this paper, we report preliminary findings on (1) promising peat swamp species that could be used in paludiculture systems and (2) how business or value chain development can help in the sustainable development of peat communities. In the discussion, we address that community participation is crucial in successful peat rehabilitation.

2. Materials and Methods

2.1. Expert consultation

We gathered information about promising paludiculture crops from peat experts during a 2-day workshop held in Banjarmasin, South Kalimantan, on July 7-8, 2019. The workshop involved peat experts from Lambung Mangkurat University ULM), Van Hall Larenstein University (VHL), Forest & Environment Research & Development Institute of Banjarbaru (FOERDIA) and local government officials. During the workshop, the option on promising paludiculture crops was discussed not only on the cultivation aspect but also on the value chain aspect. The choice of the forest and non-forest species that could potentially be used in the paludiculture system was distinguished into quick gain and long-term species (following Giesen & Nirmala [21]), with detail as follows:

- *quick gain* paludiculture species are non-timber species that provide income for farmers in the same year, and for which in general (local) markets are well established;
- *long term* paludiculture species are generally timber- or palm species that will provide income after several years only; in general, markets are established but could be improved.

The potential to combine quick gain and long-term paludiculture species was discussed based on practical experience from local paludiculture testing plots. Also, a nearby peat area was visited where discussions took place with involved stakeholders, including farmers, small-medium enterprises (SME's) and government officials. We also included results from local field trials done at the FOERDIA field site at Tumbung Nusa, Central Kalimantan.

2.2. Literature review

We reviewed the literature on peat and paludiculture species, mainly focusing on Indonesia and Malaysia. We also searched for information on the value chain of the paludiculture crops in Indonesia, particularly Sago. We involved the result of a master thesis that discussed the value chain of Sago starch in South Kalimantan Province and its SWOT analysis [22]. The information from this thesis provides information on the potential market of Sago starch in South Kalimantan Province that could be used to analyze the potential market on the national scale.

3. Results and Discussion

3.1. Potential peat swamp forest species that can be used in paludiculture systems

3.1.1. Quick gain paludiculture species. Four so-called "quick gain" paludiculture species that grow well on undrained peat and for which existing markets were identified as interesting for further testing:

- Sedge: *Purun* (*Lepironia articulata*), (handicrafts)
- Vegetable: *Pare*/Bitter gourd (*Momordica charantia)*
- Vegetable: *Kangkong*/Water Spinach (*Ipomoea aquatica)*
- Honey: *Kelulut*/Stingless bee (*Trigona spp. and/or Apis milivera*)

A detailed overview was made for each species, including a description of the type of products, the ecological characteristics and requirements, as well as the commercial potential (Table 1).

Table 1. Quick gain species that grow well on undrained peat.

Species with high economic + commercial potential that are proven to produce well on peat			
Scientific name	*Lepironia articulate*		
Local name	Purun		
First harvest	Cut after 1 year		
Product	**Ecological characteristics**	**Commercial potential**	**Image**
Handycraft like bags, mats; potential for plastic prevention (straws, bags, baskets, hats, polybags)	Fast-growing sedge species close to rivers & tidal swamps. Suitable for growing on shallow to deep peatlands with a high water table	Local markets, cheap prices Straws are already exported to Australia. High potential for intercropping and paludiculture, plastic prevention. FOERDIA already gave training for producing straws and polybags during the campaign against plastic	 *Sources: photo left: (plantsforafuture, 2020) photo right: handicraft of purun (Middelberg, 2019)*
Scientific name	*Momordica charantia*		
Local name	Paré, bitter gourd		
First harvest	90 days (3 months)		
Product	**Ecological characteristics**	**Commercial potential**	**Image**
Vegetable	Climbing species	Important local market vegetable? Used widely in Indonesia cuisine, also the market in Jakarta	 *Sources: photo left: (Zell, n.d.)photo right: (Mahalder, 2011)*
Scientific name	*Ipomoea aquatica*		
Local name	Kangkong		
First harvest	30 (-50) days (1-2 months)		
Product	**Ecological characteristics**	**Commercial potential**	**Image**
Vegetable, can be harvested year-round	An aquatic herb that roots freely at the nodes and can form large clumps of growth. Grows in wet soils	Stems and leaves above water are cut. Farmers leave the roots of plants to regenerate, and the next harvest is normally after 4-5 weeks Yields up to 90 tonnes per hectare per year in Thailand	 *Sources: Phote (van der Meer 2019)*

Species with high economic + commercial potential that are proven to produce well on peat			
Scientific name	*Trigona spp.* and/or *Apis milivera*		
Local name	Stingless bee, and/or honey bee, Kelulut		
First harvest			
Product	**Ecological characteristics**	**Commercial potential**	**Image**
Honey and propolis	The hive is placed on trunks of *Hevea brasiliensis* (rubber) (see photo on the right)	Internationally high potential for good quality/priced honey Can be in combination with many tree species, but *Melaleuca cajuputi* is especially productive	 *Sources: Photo left (Middelberg, 2019) photo right: (Kelulutman, 2012)*

3.1.2. Long-term paludiculture species. Three species with high economic and commercial potential that are proven to produce well on peat but for which markets are still developing:

- Palm: Sago *(Metroxylon sagu):* Flour and starch
- Tree: *Jelutung* (*Dyera polyphylla)* rubber, timber
- Tree: *Gelam/Kayu putih* (*Melaleuca cajuputi*): oil, honey, timber

A detailed overview of the four species is given in Table 2, including a description of the type of products, the ecological characteristics and requirements, as well as the commercial potential of the species.

Table 2. Species with high economic and commercial potential are proven to produce well on peat.

Species with high economic + commercial potential that are proven to produce well on peat			
Scientific name	*Melaleuca cajuputi*		
Local name	*Gelam / Kaya putih* (oil)		
First harvest	Young trees after 3-4 years		
Product	**Ecological characteristics**	**Commercial potential**	**Image**
Essential oil (medicinal), honey, beeswax, wood, edible mushrooms, pepper substitute, biochar	Grows naturally in peat swamp forests, grows well on degraded lands. Shallow to deep peat Grow up to 25 meters, fast-growing pioneer species. *Gelam* is a different variety from *kayu putih*, although they have the same species name. The wood of *gelam* is used for pole, while leaves of *kayu putih* are used for cajuput oil	Highly interesting because of its multiple products. State-owned plantations sold cajuput oil at 240,000 IDR/kg in 2015. Honey is sold at 175,000 IDR/kg. Cajuput oil is highly popular throughout Indonesia - supply has not been able to fulfill demand completely. Indonesia is a net importer of honey; hence there is commercial potential for locally produced honey. The local market for wood (mostly construction), the market for cajuput oil in the Moluccas, Honey in beeswax traded around Jambi. The international market potential for high-quality honey	 *Sources: photo of natural stand: (Giesen, 2008) photo Melaleuca honey: (Alibaba, n.d.)*

Species with high economic + commercial potential that are proven to produce well on peat			
Scientific name	*Metroxylon sagu*		
Local name	*Sagu*, sago palm		
First harvest	9-10 years to cut trunk for flour when cultivated on peat, but in practice not based on age but on several biophysical performances, e.g., leaf midrib, panicles.		
Product	**Ecological characteristics**	**Commercial potential**	**Image**
The pith of the stem is rich in starch, used for local dishes. Used as a natural barrier against animals. Leaves are used for thatching and weaving. Harvest trunk before flowering	Hapaxanthic – each trunk flowers ones after +- 15 years, then dies. However, one or more suckers will develop from the base and take over. Grows in coastal river banks, freshwater swamps, shallow peat areas	Flour is occasionally traded on local markets. Leaves or basketwork are traded for construction. Economic return is about 500 USD ha^{-1} $year^{-1}$ on an intensive plantation. Flour is exported to Malaysia, China, Japan and Singapore. Products made of sago flour (noodles, biscuits) are in demand nationally and internationally. Export of sago starch and flour has increased over the last years	 *Sources: photo left: (Johnson, 2020) photo right: (Cifor, 2010)*
Scientific name	*Dyera polyphylla*		
Local name	Jelutung		
First harvest	Tapping after 7 years or BHD of 25cm (tapping after year 5 at PT DHL in Jambi, Sumatra)		
Product	**Ecological characteristics**	**Commercial potential**	**Image**
Latex for chewing gum, insulation. Timber for carvings, pencils, matches, furniture. Resinous fruits used for torches and mosquitoes repellent	Good in mixed systems, sets seeds irregularly, often only every 4-5 years	Internationally: a very small amount of latex shipped to Japan from central Kalimantan. (Source: Peatland Species Value Chain Assessment Series: Jelutung, 4.1.3).	 *Sources: photo left: (Worldagroforestry, 2015), photo right: (FAO, 2013)*

3.1.3. Mixed paludiculture farming systems. Testing of paludiculture system has been implemented by FOERDIA on degraded peat swamp forest at Tumbang Nusa village, Central Kalimantan. Different species and planting regimes are tested in this area to develop a sustainable, drainage-free agroforestry system in the future. The mixing of crops has both economic and ecological advantages, like the spread of income, diversification of markets, more biodiverse systems, and a higher natural level of pest control.

[16] describes various mixed (paludiculture) systems at Tumbang Nusa (Mixed jelutung+rambutan, mixed rubber+jelutung+*Shorea balangeran*, and Enrichment planting of *Shorea balangeran*+jelutung in shrub peatlands). She found that in terms of peat restoration, these systems contribute to a recovery of vegetation and above-ground carbon stocks in comparison to the degraded peatlands. However, the cultivation systems using fertilizers may increase GHG emissions and peat decomposition. [16] also concluded that most of the tested cultivation systems could not be qualified as true paludiculture systems as the water table is not maintained at a sufficiently high level. It is therefore needed to test further native peat swamp forest species which do not need drainage at all, like *geronggang* (pulp), *jelutung* (rubber) and shorea (timber). An overview is given in Table 3 of some true Paludiculture species. Currently, several tests are underway mixing these species with other NTFP products like the stingless bee and fish pond/fish traps (*beje*). Results are still being processed and analyzed.

Table 3. Species tested at FOERDIA peat forest testing site, Tumbung Nusa, Central Kalimantan.

Plant Species	Growth	PSF species	Lesson learnt
Tumih (*Combretocarpus rotundatus*)	++	+	Fuelwood, Facilitating other species in succession
Terentang (*Campnosperma coreacea*)	++	+	Wood, pulp
Meranti (*Shorea pallidfolia*)	-	+	Wood
Gerunggang (*Cratoxylum glaucum*)	+	+	Wood, pulp
Jelutung (*Dyera polyphylla*)	++	+	Latex,
Nyatoh (*Palaquium* sp.)	+	+	Latex
Blangeran (*Shorea balangeran*)	++	+	Wood, fast-growing
Alau (*Dacrydium beccarii*)	+	+	Wood,
Punak (*Tetramerista glabra*)	+	+	Edible fruit, wood

Apart from these testing trials at the FOERDIA Tumbang Nusa site, several other local initiatives involving farmers are underway where degraded peat-lands are made valuable again with a variety of agricultural crops:

- Farm management at Kalampangan village, where the farmers use common species of vegetables from dry land like nut, chili, corn and others on partly drained peat. Some farmers combined this with fish ponds;
- Fruit orchard management at Misik village where farmer plants fruit trees like dragon fruit, orange, longan and others;
- A mixture of *jelutung* plantation and stingless bee culture at Tumbang Nusa village;
- A mixture of Rubber plant (*Hevea brasiliensis*), vegetables and stingless bee culture at Pilang, Central Kalimantan;
- Paddy plant (rice) at Kalio village, Pulang Pisau, on shallow degraded peatland with low productivity (only 3-5 ton *gabah*/ha).

Several of the crops used in these local initiatives need (partial drainage). The challenge remains to fine-tune the management of these systems so that drainage is slowly reduced and crops that require drainage are replaced by a mix of true paludiculture species.

3.2. Value chain development of promising paludiculture species – the case of Sago

Sago's palm is one of the potential long-term paludiculture plants described in Table 2 suitable for peatland rehabilitation. Sago palm (*Metroxylon sagu*) is native to the wet, tropical regions of Southeast Asia. It produces edible starch in its trunk, which is a source of carbohydrates for indigenous people [23]. In addition, the palm occurs naturally on swamp areas, can withstand flooding, and can adapt to varying soil conditions, including peat soils [23]. Thus, local farmers who grow this crop could benefit from its trade to improve their livelihoods.

[22] Studied the value chain of Sago starch in Kuala Kapuas District, Central Kalimantan Province and investigated opportunities for chain development that could help improve the livelihoods of local farmers and maintain the integrity of peatlands. The result of her review shows that the value chain of Sago in Kapuas is not very well developed (Figure 1). The Sago productions are being conducted at the scale of the home industry with a simple processing method that resulted in low quantities and poor quality of wet Sago starch. The stakeholders involved in the value chain are sago farmers, sago starch producers (farmers or villagers that owned the processing mill), middlemen, and manufacturing and retail companies.

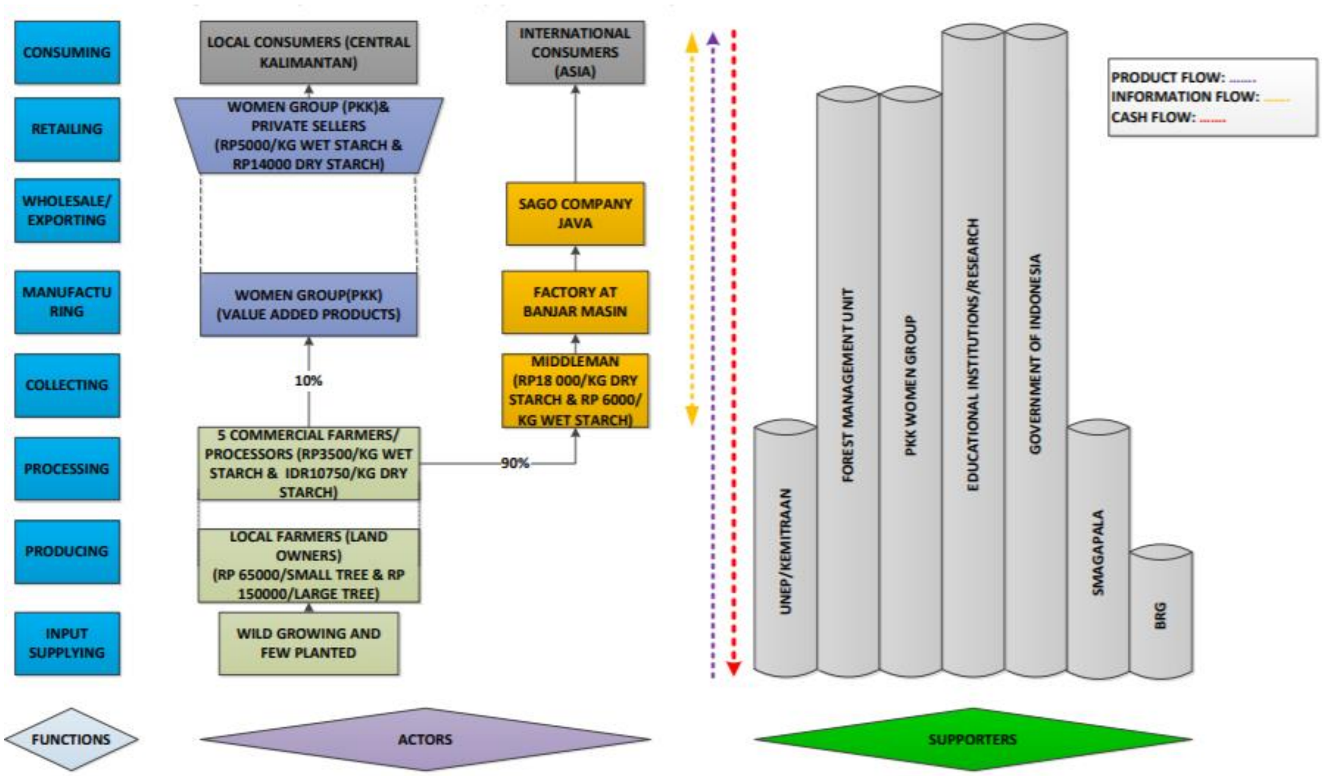

Figure 1. Sago value chain map in Kapuas Distict, Kalimantan [22].

[22] Found that Sago starch production provides sufficient economic benefit to local people (see Table 4). The data in Table 4 show that the highest benefits from producing wet starch are received by processors (42 %), while the farmers only received 13 % of the total benefits. Meanwhile, the middleman received the highest benefits from trading the dry starch (81 %).

Table 4. Value share in the sago export chain, Kapuas District, Kalimantan for wet and dry starch.

Actors	Revenue/Kg (IDR)	Added Value (price received by actor – price paid by actor) (IDR)	Value Share (Added value x 100/ Final retail price)
Wet Starch			
Farmer	769	769	13 %
Processor	3,500	2,731	46 %
Middlemen	6,000	2,500	42 %
Dry Starch			
Farmer	769	769	4 %
Processor	3,500	2,731	15 %
Middleman	18,000	14,500	81 %

Source: [22]

Table 5. SWOT analysis of sago on peat.

	STRENGHT	WEAKNESS	0PPORTUNITIES	THREATS
POLITICAL	Recommended by the government for peatland conservation and rehabilitation	Low financial support from the government to improve sago value chain		
ECONOMICAL	Sago grows wild. It does not require strict cultivation to continue growing. Possesses low glycaemic index and gluten-free starch	Sago's palm takes about 8-15 years to grow from sprouting to harvest. There is low global demand for sago starch	Opportunities for carbon credits by engaging in carbon farming practices	
SOCIAL/ CULTURAL	Representation of both genders in sago starch production Sago businesses are family owned Cherished during festivities	Discrimination of the starch as food by the financially privileged in Indonesia	Opportunities for use in food security	Confusing other starches like tapioca to be sago starch is a threat to effective marketing of sago starch
TECHNOLOGICAL	Availability of traditional processing machinery	Poor processing plants available for starch extraction and drying Poor transport methods Traditional harvesting and processing equipment are not sufficient for proper production	Opportunities for innovative use of sago starch in	Emissions from processing machinery could be a threat to the carbon footprint in the sago value chain
ENVIRONMENTAL	Grows well on peatland areas Useful in the rehabilitation of degraded peatlands Can withstand flooding and salinity		Sago forests can improve biodiversity and ecosystem service. Has potential in the mitigation of greenhouse gases	Climate conditions hinder starch drying The nature of peat soil hinders effective harvesting

Source: [22]

Challenges hindering the value chain are production issues (e.g., long time before production starts), poor chain coordination, poor quality of the starch, and poor processing (e.g., mainly done manually). These combined issues lead to difficulty gaining access to markets (see SWOT analysis results in Table 5). However, several opportunities are also indicated, such as combination with carbon markets and which can help to improve further the attractiveness of Sago as a paludiculture crop for local communities (Table 5). Also, biodiversity and other ecosystem services are higher in the semi-natural sago-palm forests compared to monocultures like oil palm plantations.

Further improvement of the value chains of other crops than Sago, such as the selected species in Tables 1 and 2, are also needed. It is also important to establish better links between crops/products and markets. Proper value chain analysis and development of new markets will stimulate the cultivation of crops, enhancing food security at the regional levels. It is also important to include capacity building in paludiculture practices and potential product development, including local SME's involved.

3.3. Involvement of local stakeholders

During a field visit as part of the peat workshop in July 2019, a local farmer in Kayu Tangi, Banjarbaru, South Kalimantan, who is also the head of the local farmers' group, recognized the problems of cultivation on peat. He was keen on finding alternative business models which are more sustainable. He was also looking for ways to explore paludiculture production and marketing further. Also, the group owners of a small shop selling baskets and bags made of purun (*Lepironia articulate*) were looking for support to strengthen their business's capacity and value chain development. These observations are supported by other studies on value chain development, showing that the development of products and markets can significantly boost local farmers' local production opportunities and income [22].

It is argued by [24] that the participation of local communities is essential for the sustainable management of natural resources. Based on a study interviewing 100 respondents living adjacent to North Selangor PSF, Malaysia, they found that despite the minimal direct benefits from the PSF, respondents were motivated to conserve the PSF conservation through community-based rehabilitation, fire protection, tree planting etc. [24]. [25] State that local communities should be involved in replanting, restoration and rehabilitation programs, as well as legal access and user rights to the NTFPs. In addition, there should be an agreement on benefit sharing for harvesting timber species.

The challenge lies in finding alternatives for degraded and/or drained peatland agriculture areas such as oil palm, which: (1) can reduce the trade-offs between economic and environmental benefits, and (2) can rehabilitate the ecological functions of degraded peat forest and restore their ecosystem services for local and global communities. One scenario could be to gradually phase out oil palm from peat areas and replace them with wet systems (paludiculture) resistant to higher water tables [19, 21, 26, 27] and that could sustain local communities [18, 20, 28].

Another scenario could be to restore large areas of severely degraded peatlands that are currently not being used ("wastelands"). [19] indicates that alternative paludiculture systems can provide more direct and indirect ecosystem services than, for instance, oil palm plantations on peat. They also indicate that sustainable peatland restoration through paludiculture is only possible when involving a range of stakeholders, including farmers and local communities, small and medium-sized enterprises, as well government and non-governmental organizations.

4. Conclusion

Many native peat swamp forest species in combination with crop species that require no drainage could be used in the paludiculture system in Indonesia. Results from our expert consultation and literature review show that a combination between forest species and crop species could generate short, medium and long income to local communities. Paludiculture also has important environmental benefits compared to existing, drainage-based peat cultivation systems, especially when a mix of different plants and crops is used. In addition, the cultivation of sago can have a positive contribution in providing economic benefits to all actors, including local farmers, although improvements could be made to the value chain for better value sharing. The combination of the environmental and economic benefits is an important incentive to develop paludiculture systems further to improve current peat management systems and assist further peat restoration in Indonesia. The development and implementation of paludiculture systems, particularly species selection, should have more community participation to ensure the sustainable restoration of degraded peat areas.

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