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Paludiculture: can it be a trade-off between ecology and economic benefit on peatland restoration?

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Abstract. Restoration of degraded peatlands has been taken into serious action in Indonesia. Paludiculture, which is defined as a cultivation on wet and rewetted peatlands, has been promoted as a solution of peatland restoration. The drained peatland should be blocked and rewetted to increase water table and reduce emission. While planted suitable plants and trees on wet and rewetted peatlands which have economic benefit is challenging. We conducted review and synthesis based on published and unpublished papers resulted from activities of peatland restoration in Indonesia, to show whether paludiculture may provide a balance of both ecology and economic benefits. Results show that rewetted on degraded peatlands reduces green-house-gas emission. However, few tree options for wet and rewetted peatland restoration which provides economic benefit. Tree selection usually based on specific site, price and market. Peatland restoration is complex, therefore the paradigm of peatland restoration should focus on socio-ecological restoration first. Economic benefit will come later as both tangible and intangible economic benefits. Economic friendly schemes, such as REDD+ and rewards for environmental services (RES) may be more suitable as a trade-off in peatland restoration.

1. Introduction

The Indonesia's peatlands account for 46.92% of the total peatlands in the world [1]. The difference in peatland area from the two references is due to differences in the criteria used in defining peat. The presence of organic matter below the surface causes peat soils plays role as carbon sinks [2, 3, 4, 5]. Indonesia's peat ecosystems store carbon reserves of 28.1 Gt C, with a range of 13.6 - 40.5 Gt C [6]. The estimated range of peat carbon stocks is quite wide, because it uses two different peat map sources, and both maps use different definitions of peat [6].

In addition, peat ecosystem plays an important role as a water source and regulator of water, because peat has a very large water storage capacity [7, 8]. Peat can absorb water 1 to 13 times its weight [9], as well as various other biodiversity, which can be used as a food source (carbohydrates and protein), a source of non-wood forest products, such as sap, fruit, rattan, and others [10, 11].

Peatlands in Indonesia have been managed and utilized since years ago, as agricultural and forestry lands [12, 13, 14]. Peat swamps are not suitable for farming agriculture systems. Therefore, to be suitable as agricultural farming systems, the land management practices are carried out, particularly development of canal to drain peat water [12, 14]. In addition, slash and burnt is also carried out [14, 15]. Canal drains peat water, so that it becomes prone to fire. The opening of peatlands causes the peat to oxidize, the peatland subsidizes, the rate of peat compaction increases and GHG emissions increase. Forest clearing, canals, and peatland management will emit carbon stored in the atmosphere as greenhouse gases emission (GHG) [4, 16]. CO₂ emissions due to the oxidation of peatlands in Sumatra and Kalimantan in 2015 were reported at 98.0 Mt per year [5]. This condition is exacerbated if forest



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and peatland fires occur. Due to forest and land fires in Indonesia in 2015, estimated CO₂ emissions of 1.1 Gt CO₂e [17].

High human activity in forests and peatlands by clearing forests and land and canals development, causing a high rate of peatland degradation. Peat swamp forests in Sumatra and Kalimantan are reported to have damaged 225,000 ha annually. Based on calculations from 2007 to 2015, the area of degraded forest and peatlands in Indonesia (especially Sumatra and Kalimantan) reached 6,453,730 ha. Degraded peatlands generally take the form of conversion of peat swamp forests to Acacia plantations and oil palm plantations with massive canal development [5]. The destruction of forests and peatlands in Indonesia is at an alarming rate, so that Indonesia is the highest carbon emitter country in the world [18].

To overcome this problem, restoration of degraded peat is an important target of Indonesia's development. In the national agenda, restoration of degraded peat is targeted to be 2.4 million ha by 2019. This national agenda is in line with the target of reducing greenhouse gas (GHG) emissions by 29% by 2030 at domestic costs. Therefore, restoration of degraded peat ecosystems plays an important role in addressing climate change. The Ministry of Environment and Forestry has set priorities for peat restoration, based on peat dome criteria, peat fire incidents, and areas non-concession, into 8 priority classes. The first priority, covering an area of 416 thousand ha, is a burning peat dome area and not a concession area. The total area of the eight priority restoration areas is 25.4 million ha, or the same as the total area of the Indonesian Peat Hydrological Unit [19]. In accordance with Government Regulation (PP) of the Republic of Indonesia No. 57 of 2016 junto PP No. 71 of 2014, mitigation of damage to peat ecosystems in areas that have received management permits is the responsibility of the permit holder. Recovery of peat ecosystems is carried out in three ways, namely rehabilitation, restoration, and/or other methods that are appropriate to the development of science and technology. According to [20] peatland rehabilitation aims to improve ecosystem processes, land productivity and ecosystem services, however, rehabilitation activities cannot always rebuild the original biotic integrity, in terms of plant species composition, community structure and ecosystem function.

The most prominent effect of peatland restoration to the ecosystem relates with reducing CO₂ emission [21, 22]. In the climate change convention, climate change control is carried out through mitigation and adaptation. Mitigation is all activities that can reduce CO₂ emissions into the atmosphere and increase CO₂ sequestration through peat rehabilitation and restoration [23]. As for adaptation, it is the ability of humans to adapt to climate change [24]. Adaptability is related to the ability to increase sources of income and the level of community welfare. Therefore, agriculture on peatland has to apply climate smart agriculture which maintains low CO₂ emission by maintaining high water level [25].

This is a review paper, which synthesis of paludiculture and peat ecosystem restoration in relation to climate change mitigation and adaptation, based on the results of research conducted on tropical peatlands, especially Indonesia, from literature sources that have been published and not yet published.

2. Method

2.1. Materials

Materials used in this review paper are 46 articles (unpublished and published) in peer reviewed journals, proceedings, magazines, books, and regulations.

2.2. Procedure

This paper is a narrative review. The method used in the preparation of this paper is descriptive analysis and synthesis of literature, sourced from research activities in tropical peatlands. Forty-six articles those published in peer-reviewed journals, proceeding articles, statistical data, articles in semi-popular media, and unpublished papers (such as presentation materials and reports) are collected, reviewed and synthesized. The impact of restoring disturbed peat ecosystems through hydrological

restoration and rehabilitation of vegetation on degraded peatlands against climate change mitigation and adaptation is systematically discussed.

3. Result and discussion

Land clearing and canal construction sacrifice natural vegetation that grows on it, by cutting down the native peat swamp trees species. Canal development causes peat degradation: peat water is drained, peat surface subsides rapidly, and peat density increases. At the same time, aerobic conditions on peat not only occur at the top, but in a deeper peat layer. This accelerates the rate of decomposition of organic matter. The acidity of peat water increases due to drainage. Oxidation of peat organic and inorganic material increases and proton release into the system increases peat acidity. As a result of increased oxidation, CO₂ and CH₄ emissions to the atmosphere increase [26, 27].

In the Minister of Environment and Forestry Regulation no. P.15/MenLHK/Setjen/Kum.1/2/2017 concerning Procedures for Measuring Groundwater in Peat Ecosystem Arrangement, determined the restoration technique of hydrological functions is carried out in several ways, namely the construction of canal blocking, dam construction, canal dumping and pumping water into peatlands. Rewetting peat which experiences drought due to over-drained is carried out using the same technique. Hydrology restoration has an impact on climate change mitigation and adaptation.

The construction of canal blocking is highly recommended in the restoration of degraded peat, canal blocking aims to prevent excessive peat water out and increase groundwater level (groundwater level). This has an impact on reduced peat oxidation, CO₂ emissions and subsidence [28, 31], and reduced dissolved organic carbon (DOC) [31, 32], and increasing peat moisture, thereby reducing fire susceptibility and accelerating natural regeneration [28, 29, 30, 31].

3.1. Hydrology Restoration

Hydrology restoration is one part of peatland restoration. According to the regulation, the drained peatlands are restored by blocking the canals permanently in the protection function of PHU, or applied water management in the cultivation function of PHU. Drained peatland increases GHG emission [18, 21]. The impact of global warming from each GHG is called Global Warming Potential (GWP), which is the total energy needed by a gas to emit 1 ton of gas for a certain time (usually for 100 years), compared to 1 tonne of CO₂ emissions [32]. GWPs in plantation and agricultural areas on rewetted tropical peatlands and in drained peatlands were measured and reported. Rewetting peatlands can significantly reduce GWP in plantation and agricultural areas, compared to drained peatlands [31]. Rewetting can reduce CO₂, N₂O and DOC emissions, and increase CH₄. Through controlled rewetting, overall net GHG emissions have dropped significantly. The reduce of CO₂ flow in the peat water by canal blocking using rubber composite is also reported in South Sumatra [33]. To prevent the increase in methane gas emissions (CH₄), waterlogging conditions due to rewetting are sought no higher than the land surface [34], or a maximum inundation height of 10 cm [31], therefore water management is crucial in hydrology restoration.

The acceleration of natural regeneration through hydrological restoration is possible due to the recovery of peat conditions, so natural regeneration may occur through natural dispersal agents. Composite dam technique, which fills in the dam with mineral soils and planting the native tree species and leave the trees grow. The root systems inhibit the water flow and maintain the dam because the ability of roots to bind peat or mineral soils that filled into the dam [29, 35]. Plants that grow due to natural regeneration will increase net primary production (NPP) [36]. The composite dam technique has been developed in several locations on drained peatlands, such as in Block C, a former mega-hectare mega rice project [29], in Block A, a former mega million-hectare mega project, Sebangau National Park in Central Kalimantan, and the Merang River region in South Sumatra. In a narrow canal, canal blocking with spill-way is usually developed [35] (Figure 1).

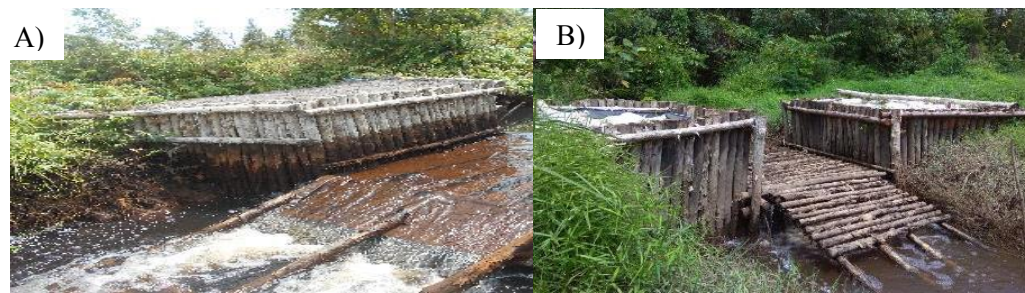


Figure 1. Canal-blockings with spill-way using poles and plank

Hydrological restoration does not only affect climate change mitigation, but also people's adaptation to climate change. The construction of canal blocking can be utilized for freshwater fish farming, through community empowerment programs in the social forestry schemes. For example: villagers of Kepayang Village at Bayung Lencir Sub-district, South Sumatra Province have obtained a Decree of the Minister of Forestry with Forestry Minister Decree Number No. 573/Menhut-II/2013 concerning the determination of Kepayang Village Forest, covering an area of 5,170 ha. In 2016, composite dam construction was carried out on several canals around Kepayang Village Forest. Our study in 2016 showed that, production of freshwater fish, such as cork fish, has increased since the construction of canal blocks. Through the village community empowerment program, a project helped farmer groups process the results of peat restoration activities and sell their products to companies around the village area.

An increase in freshwater fish population due to the construction of canal blocks has also been reported in the Sebangau River. The impact of canal blocking development should be seen in the long-term goal of peatland ecosystem restoration. The fill-in canal blocking construction in Sebangau, Central Kalimantan accelerate the process of natural revegetation of degraded peat. Blocking canals reduce CO₂ emissions; and increases carbon sequestration through increasing biomass [29].

3.2. *Revegetation Effect*

In the restoration of degraded peat ecosystems, rehabilitation of vegetation has been widely practiced among the communities, not only as a government (central and regional) program, but also by national and international NGOs. Vegetation rehabilitation by considering the suitability of plant species and peat conditions are priority criteria for species selection. In addition, consideration of economic value commodities that provide alternative livelihoods for the community also needs to be considered.

Taking into account the characteristics of the peatland hydrological unit (PHU), namely the presence of peat domes that protect water systems and carbon sources, the choice of species and rehabilitation techniques for vegetation will differ depending on the function of the PHU, namely the protection function and the cultivation function. Some vegetation rehabilitation techniques that can be developed are paludiculture and agroforestry on peatlands. Paludiculture is cultivation with natural types of peatlands that are ecologically and economically beneficial [11, 40] (see Figure 2), and can be conducted in the protection function of PHU. In the cultivation function PHU with the, species selection can be more varied, by combining agricultural commodities with forestry commodities. Planting of these types of combination plants can be done with a number of techniques or cropping patterns [37, 38, 39]. Rehabilitation of vegetation on degraded peatlands in the long run will have both positive and negative impacts on ecology. Not all farming system on peatlands will reduce carbon emission, because farmer's managements, such as fertilizer and canal development, effect negatively to the environments [40].

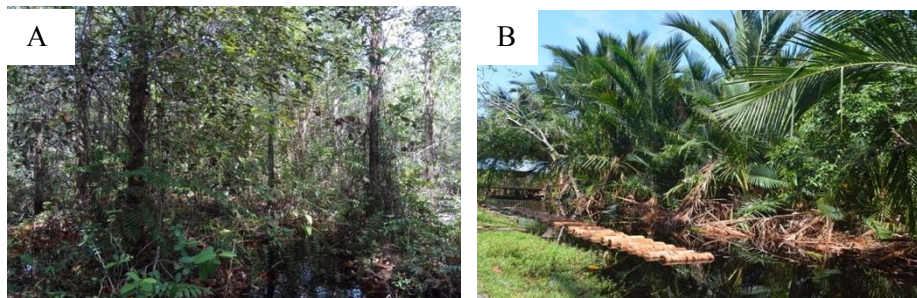


Figure 2. Paludiculture on peatlands. A. After 10 years rehabilitation of burned peat swamp forest in Sebangau National Park. B. Smallholder sago plantation in Sungai Tohor, Riau

In the restoration activities of degraded peat ecosystems, it is strongly recommended to plant local species that are peat-friendly, has economic values, and not an invasive species, or known as paludiculture [11, 25]. A farming system in the natural peat swamp which has economic value is sago. Planting sago on peat swamp peatlands positively reduces greenhouse gas emissions in this case CO₂ [40]. This is because carbon stocks in shrubs are lower than sago. However, if sago is planted in the forest area (both secondary and primary), then the net emission value is positive, which means there are still CO₂ emissions, respectively of 3 and 28.4 Mg CO₂/ha/year. The ability of sago to reduce the value of emissions does not comparable to planting rubber and palm oil in swamp shrubs. Net emissions from oil palm and rubber plantations are much lower than sago [40].

3.3. *Economy Impact of Peatland Restoration*

Vegetation rehabilitation on peatlands positively influences community adaptation to climate change. Planting the right types and appropriate can be an alternative source of livelihood for the community, and can provide economic benefits. Various types of commodities can be planted on peatlands and have economic value to the community. However, many of them require the practice of water management. The communities have little interest on the natural types of peat swamps that are resistant to wet peat and rewetted conditions, because they are considered to have little economic benefit. Some types that are considered having economic value and are feasible to be developed are sago, jelutung, rattan, gemor, gelam and tengkawang [11]. But only a few reports describe the economic viability and 'Opportunity Cost' of the paludiculture commodity. The opportunity cost of reducing CO₂ emissions is the estimated value of the increase in land productivity achieved within a certain period of time, expressed per unit of equivalent CO₂ emissions.

Sago as a paludiculture commodity, is a food source and can also be used in the bio-ethanol industry. The economic value of sago in Papua is relatively high, with a Net Present Value (NPV) of 441 USD/ha/year and can provide economic benefits for the community. The Opportunity Cost calculation of -28.62 USD/Mg CO₂, shows that planting sago on shrub land can increase economic value and reduce CO₂ emissions [41].

In addition to sago, jelutung is one of paludiculture species which produced high economic value latex. Jelutung planted in a monoculture pattern on peatlands in Jambi had an NPV value of 3,590 USD/ha. This value is higher than the monoculture rubber NPV, amounting to 1481 USD/ha [42]. Whereas NPV monoculture jelutung in Central Kalimantan was reported at Rp 9.9 million/ha [43]. This value meets the eligibility criteria in the farming system.

Peat swamp forest has carbon stocks, both above and below the surface, so the conversion of forests to plantations (both HTI and plantation commodities) significantly reduces carbon stocks and increases CO₂ emissions [41, 45, 46]. The opportunity cost value of peat swamp forest conversion with other commodities is very high, and cannot be compensated by incentive mechanisms [45, 46]. Therefore, peat swamp forests should be conserved.

Yet, lack reports on the estimated value of carbon emissions and Opportunity Cost calculation of potent commodities of paludiculture species, such as purun, gerunggang, gemor, and others. Therefore, further research is still needed for the types of paludiculture carried out through peatland planting activities.

4. Conclusion

Paludiculture as part of degraded peatland restoration is a national agenda that is also in line with the international agenda in order to control the impacts of climate change. Peat ecosystem restoration activities through the restoration of hydrology and rehabilitation of vegetation have been proven to be able to mitigate the impacts of climate change and at the same time increase community adaptation to climate change. The active role of the community in peat ecosystem restoration activities is needed so that it can provide direct benefits to the environment and the community in the long run.

The ability to adapt to climate change for people needs to consider the economic benefits. Therefore, commodities developed from vegetation rehabilitation and hydrological restoration activities shall provide economic benefit, and markets are available for these products and guaranteed prices are stable. Commodity value-chains developed in the restoration and rehabilitation of degraded peatlands need to be considered. Paludiculture is a trade-off between ecology and economic benefit.

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