Chapter 7
Sustainable Management Model for Peatland Ecosystems in the Riau, Sumatra

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Abstract The peat swamp forest of the Riau Biosphere Reserve has been degraded at an alarming rate. The development of large areas of peatland as timber estates and palm oil plantations has caused a serious threat to the remaining peat swamp forest ecosystems. Forest and land fires have occurred annually, especially in the dry season, and the remaining peat swamp forest is subject to illegal logging activities and natural disturbances. Villagers continuously convert the remaining natural peat swamp forest into jungle rubber gardens and oil palm plantations. Four objectives of the study: (1) to clarify the current condition and ecological characteristics of the remaining peat swamp forest ecosystems, (2) reestablishing typical canopy tree species and restoring degraded peat swamp forest and peatland areas, (3) to determine a mechanism or directions for the participation of the local population; and, (4) to discuss a model for the promotion of sustainable management of peat swamp forest ecosystems in the biosphere reserve. The improvement of management of remaining peat swamp forests and rehabilitation should consider the unique ecological characteristics particularly the dominant tree species, fast growing species as well as the peat characteristics. The remaining peat swamp forests should be kept in their natural conditions in order to provide continuous ecosystem services, given their unique biodiversity characteristics, protection could be enhanced by adding incentives to local communities including monetary incentives from biodiversity and climate change mitigation funds. The promotion of a sustainable management model should be the direction of actions to conserve the remaining natural forests, regenerate and restore the degraded peat swamp forests, and create economic incentives enabling sustainability for the local community.

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7.1 Introduction

The main area reported in this paper is located at the Giam Siak Kecil-Bukit Batu Biosphere Reserve of Riau Province in the coastal area of the east of Sumatra Island. Riau province covers an area of about 9 Mha. The Giam Siak Biosphere Reserve has a total area of 698,663 ha and is located between 0°44′–1°11′N and 0°11′–102°10′E in two districts (Bengkalis and Siak) and one city (Dumai), in Riau Province, Sumatra Island, Indonesia. Topographically, most of the terrain is at altitudes of 0–50 m a.s.l. Having the largest peatland area in Sumatra, Riau province plays a very significant role to the local environment as well as in the global environment.

Peatlands are huge deposits of organic carbon and the alteration of their natural condition has the potential to release the stored carbon at levels that may affect the global climate. Hooijer et al. (2006) estimated that between 1997 and 2006, regional peatland fires caused average annual CO_2 emissions of 1400 Mt (with 90 % of this originated in Indonesia, mostly from Riau in Sumatra). This is equivalent to almost 8 % of all global emissions from fossil fuel burning. A further 600 Mt year^{-1} is emitted by Indonesia due to the decomposition of drained peat. Following conversion to oil palm plantations, the water is typically drained to a depth of 1 m which causes subsidence of the peat of about 10 cm year^{-1} and emitting around 130–180 tons CO_2 year^{-1} ha^{-1} (Pearce 2007).

With a total area of 22.5 million ha, Indonesia has the largest peatland area in the tropical world (Page et al. 2010), and the Sumatra share is about 8.3 million ha or 30.7 %. Almost half (4.0 million) is located in Riau Province. By having the widest tropical peat-swamp forests in Sumatera, Riau certainly has an important role to promote sustainable management of peatland, especially for adaptation and mitigation of global warming impacts. Riau will have the position to determine of deciding to the fight for carbon emission reductions in Indonesia and also in the rest of the world. Unfortunately, most of the area of Riau has been deforested and converted to agro-silvocultural lands. The rest is left as shrublands and the drying peat is prone of fires. Currently, the only remaining tropical peat swamp forest is in the form of forest blocks with relatively pristine conditions. An area in this ecosystem whose status has been upgraded and has been designated as a Biosphere Reserve by UNESCO in 2009 is the Giam Siak Kecil – Bukit Batu (GSK – BB) in Riau Province (Gunawan et al. 2012). The main purpose of this designation is for conservation and sustainable development of the area. The landscape was divided into three zones: core, buffer, and transition. The core area is set aside for forest conservation, while the buffer and transition areas are allocated for economic activities. The Biosphere Reserve is unique because 75 % of its total area is covered by peatland. The poor management and land conversion, however, has resulted in a loss of almost 300,000 ha of natural peat swamp forest from 1998 to 2002. Moreover, forest fires occurred annually, especially in the dry season, and the remaining peat swamp forest was subject to illegal logging activities and natural disturbances. A significant part of the core and buffer areas have also been converted by the villagers into jungle rubber gardens and oil palm plantations (Gunawan et al. 2012).

Until the end of 1980s, the peatswamp forest ecosystem in the Giam Siak Kecil-Bukit Batu area supported the livelihood of local communities. The timber and various non-timber forest products provide subsistence for the local community. However, during the 1990s, dramatic changes took place in the area as forest concession-holding (HPH) companies conducted large-scale commercial logging operations. At the beginning of 2000s, even more dramatic change occurred, since much of the Productive Forest was converted to Industrial Forest Estates (HTI). These changes have limited access for local communities to forest products and forest land, the system inherited from generation to generation, to support their livelihood. Such deprivation induced local community involvement in illegal logging activities that spread throughout the area during 2002–2008. Such activities were stopped by force by the government. Unfortunately, little attention has been paid to provide non-destructive but income-generating activities to locals.

One of the serious problems in sustainably managing peat swamp forests is their current state of severe degradation. Compared to relatively good forest conditions, these degraded forests need innovative rehabilitation activities. In the Biosphere Reserve, land conversion and poor management have caused the loss of around 300,000 ha of natural peat swamp forest within the past 17 years (Jarvie et al. 2003). In addition to companies, local villagers also converted lands along the Bukit Batu river basin for rubber jungle gardens. The villagers used to plant jungle rubber as markers for their land but nowadays, younger villagers extend and convert more natural forest to establish wider areas of rubber jungle cultivation. As a result of these land conversions and loss of drainage, forest fires occur annually, especially during the dry season further worsening land degradation. Meanwhile, the remaining peat swamp forest in the core area of the Biosphere Reserve is subject to illegal logging activities. Local people used to gather timber and non timber forest products such as seeds of *Palaquium sumatranum* to produce oil for cooking, white latex from *Dyera lowii* and *Payena lerii*, and bark of *Alseodaphne cratoxylon* used as mosquito repellant. Other trees provide medicine and fruits. Nowadays, however, these forest products have gradually decreased with the deforestation and degradation of the natural peat swamp forests. Moreover, the Bukit Batu forest block was declared a conservation area in 1999 by the Central Government through the Forestry Department. This move demarcated conservation area boundaries separating areas claimed by villagers where there are jungle rubber gardens. An intensified conflict between the government and villagers has emerged and without appropriate forest conservation and management measures that address the livelihoods of the villagers, conservation will not succeed and forest degradation will continue.

This paper highlight the following: (1) to clarify the current condition and ecological characteristics of the remaining peat swamp forests ecosystem, (2) reestablishing typical canopy tree species and restoring degraded peat swamp forest and peatland areas, (3) to determine a mechanism or directions for local community participation; and, (4) to discuss a model for the promotion of sustainable management of peat swamp forest ecosystems in the biosphere reserve.

7.2 Characteristics of Mixed Peatland Forest (MPF) and Bintangur Forest (BF)

Table 7.1 details the Mixed Peatland Forest (MPF) and Bintangur Forest (BF), their distinct dominant species, floristic composition, diversity, and local environmental characteristics. These results listed here will have important implications for future

Table 7.1 Forest types and their local environmental characteristics

Sampling plot	Species	Local environmental characteristics	Forest type
Plot 1	*Diospyros hermaphroditica*	Much water on the forest floor, 50–100 m from river, peat depth >6 m, *Pandanus* spp. Present	MPF
	Calophyllum lowii		
	Eugenia paludosa		
	Shorea spp.		
	Durio acutifolius		
Plot 2	*Eugenia paludosa*	100–150 m from the river, peat depth >6 m, dense *Pandanus* spp.	MPF
	Shorea teysmanniana		
	Diospyros hermaphroditica		
	Calophyllum lowii		
	Durio acutifolius		
Plot 3	*Palaquium sumatranum*	Little or no surface water, relatively flat micro- topography, 50–100 m from the river, peat depth >6 m, asam paya (*Salacca conferta*) present	MPF
	Diospyros hermaphroditica		
	Mezzetia parvifolia		
	Shorea teysmanniana		
	Mangifera longipetiolata		
Plot 4	*Eugenia paludosa*	Ten years after selective logging, 150–1000 m from the river, peat depth >6.5 m. In the rainy season, water present 150 m from the river, asam paya (*Salacca conferta*) present	MPF
	Madhuca motleyana		
	Diospyros hermaphroditica		
	Xylopia havilandii		
	Palaquium sumatranum		
Plot 5	*Calophyllum lowii*	Wind and indirect fire disturbance, surrounded by drainage canals and pulpwood plantation, approximately 23 km from the river, peat depth >10 m, *Calophyllum lowii* the dominant species	BF
	Shorea teysmanniana		
	Eugenia paludosa		
	Tetractomia tetrandum		
	Mangifera longipetiolata		
Plot 6	*Calophyllum lowii*	Approximately 23 km from the river, wind and indirect fire disturbance, surrounded by drainage canals and pulpwood plantations, peat depth >10 m	BF
	Shorea teysmanniana		
	Plantonela obovata		
	Mangifera griffithii		
	Eugenia paludosa		

Table 7.2 Regeneration performance of the six main upper-story peat swamp forest trees

		Number of stems (DBH <10 cm)									
		Plot 4[a]			Plot 5[b]					Plot 6[c]	
		Sub-plot			Sub-plot					Sub-plot	
Species	Family	1	2	3	4	5	6	7	8	9	10
Calophyllum lowii	Clusiaceae	3	0	0	50	14	51	16	24	0	1
Shorea teysmanniana	Dipterocarpaceae	1	1	0	1	0	1	2	0	0	0
Palaquium sumatranum	Sapotaceae	0	54	24	0	0	0	0	0	0	2
Shorea uliginosa	Dipterocarpaceae	0	0	0	0	3	0	0	0	0	0
Tetramerista glabra	Theaceae	0	0	0	6	0	7	0	0	0	0
Gonystylus bancanus	Thymelaeaceae	0	1	5	0	0	6	0	0	0	0

[a]Logged-over forest
[b]Wind-disturbed forest
[c]Burnt forest

Table 7.3 Regeneration performance of the six main upper-story peat swamp forest trees after 1 year

		Number of stems (DBH <10 cm)									
		Plot 4[a]			Plot 5[b]					Plot 6[c]	
		]Sub-plot			Sub-plot					Sub-plot	
Species	Family	1	2	3	4	5	6	7	8	9	10
Calophyllum lowii	Clusiaceae	1	0	0	106	26	70	29	44	0	3
Shorea teysmanniana	Dipterocarpaceae	1	5	0	1	0	1	2	0	0	0
Palaquium sumatranum	Sapotaceae	0	44	19	0	0	0	0	0	0	2
Shorea uliginosa	Dipterocarpaceae	0	1	0	0	3	0	0	0	0	0
Tetramerista glabra	Theaceae	0	0	0	6	0	7	0	0	0	0
Gonystylus bancanus	Thymelaeaceae	0	2	5	0	0	6	0	0	0	0

[a]Logged-over forest
[b]Wind-disturbed forest
[c]Burnt forest

restoration and conservation efforts – on what species to plant and how to consider the natural succession. We used the Important Value (IV) index. The species with the highest IV index were considered to be the most "dominant" in a plot.

The regeneration performance of the six main upper-storey tree species was also examined. *Calophyllum lowii* has the best regeneration performance in the wind-disturbed forest plots, but the performance is poorer in the logged-over and burnt forest plots. It is not regenerated in sub-plots 2 and 3 in the logged-over forest or in sub-plot 9 of the burnt forest (in Table 7.2).

One year after the monitoring, the composition and regeneration performance had not changed significantly (Table 7.3). The number of stems of the *Calophyllum lowii* and *Palaquium sumatranum* had changed whereas both of these species differ in their regeneration performance. *Callophylum lowii* show increase number of stems. In the other hand *Palaquium sumatranum* decrease in regeneration performance that showed in lower of number of stems than in *Callophylum sumatranum*. Other typical canopy tree species show limited and even absence of regeneration in some of the sampling plots.

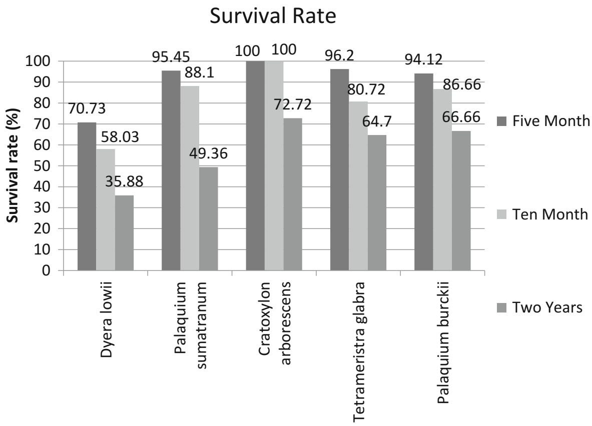

Fig. 7.1 Survival rates of seedling

For restoration experiments in logged over forests show in general, survival rates show a decreasing trend in all planted tree species. The survival rates of the seedlings after 5, 10 months, and 2 years of monitoring are presented in Fig. 7.1. The survival rate within 5 months ranges from 70.73 to 100 %, at 10 months after planted ranging from 58.03 to 100 %, and it drastically decreased 2 years after planting to a range of 35.88–66.66 %. The overall higher survival rate of tree species was *Cratoxylon arborescens*, *Palaquium burckii*, and *Tetramerista glabra* with ranges from 68.02 to 96.8 %. The lowest survival was for *Dyera lowii* with 35.88 %.

As shown in the results, the survival rate of peat swamp forest species during 5 and 10 months and 2 years of monitoring varies between species. Species with high survival rates (68.02–96.8 %) include *Cratoxylon arborescens*, *Palaquium burckii*, and *Tetramerista glabra* in both hill and normal planting methods using Gap experiment. A species with a low survival rate is *Dyera lowii*. Treatment to create more open gaps is important for improving survival and growth of this species.

7.3 Biomass, Carbon Content, and Carbon Sequestration in Mixed Peatland Forest

Biomass was estimated form allometric equation. The total aboveground biomass in each plot was also estimated using an allometric equation developed by Brown (1997). The Allometric equation was developed for tropical forests using data collected by several authors from different tropical countries and at different times. The allometric equation is:

$$Y = \exp(-2.134 + 2.53 * \ln(D)) \quad (7.1)$$

Where Y = total above-ground biomass in kg/tree; and D = diameter at breast height (DBH in cm). The above ground carbon storage was calculated by assuming that the carbon storage is 0.47 of the total above ground biomass (Brown and Lugo 1982; Brown et al. 1989; Houghton et al. 1997). For the quantification of carbon sequestration during a period of time, the most common method is based on the amount of carbon fixed in the biomass at a specific time, usually the end of a rotation period. This was referred to here as "carbon fixed" and it can be exemplified as the amount of carbon stored in planted trees at a certain time **t** after planting.

Total amounts of aboveground biomass and carbon accumulation were increasing during the 2 years of rehabilitation in logged over mixed peatland forest (Fig. 7.2). Biomass increased from 2.94 to 32.51 Kg ha^{-1}, and carbon storage increased from 1.55 to 16.28 kg C ha^{-1} in the experimental sites. Carbon sequestered by vegetation rehabilitation increased from 3.77 to 14.07 Kg C ha^{-1}.

Increases in biomass, carbon storage, and carbon sequestration in forested areas by natural regeneration processes in logged over mixed peatland forest are shown in Fig. 7.3. The forest recovery through natural processes contributed in sequestrating carbon of 0.71 Mg C ha^{-1} within 2 years of monitoring. There was an increase in biomass from 3.88 to 5.3 Mg ha^{-1} and carbon storage of 1.94–2.65 Mg ha^{-1}.

In this research, the effect of vegetation rehabilitation and natural regeneration processes on the total accumulation of carbon storage was counted. Our results

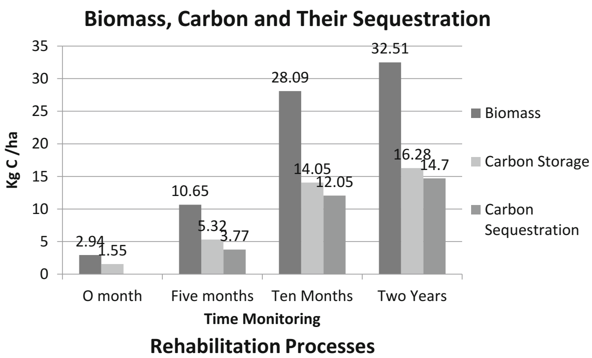

Fig. 7.2 Carbon sequestration in rehabilitation plots

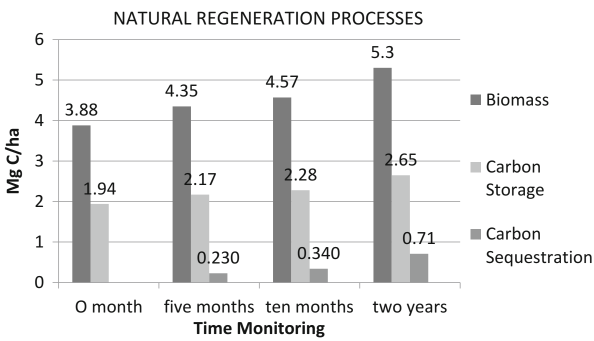

Fig. 7.3 Carbon sequestration in forest regeneration naturally

showed that the total amount of carbon sequestration was 0.72 C Mg ha^{-1} in both the experimental sites and forested areas which indicates that the combination of forest recovery by vegetation rehabilitation and natural regeneration processes have the potential to enhance carbon storage among the various forest rehabilitation efforts that may be contemplated.

Mixed Peat Swamp Forest and Bintangur Forest – and details their distinct dominant species, floristic composition, diversity, and local environment characteristics. These data could have important implications for future restoration, or conservation efforts – on what species to plant and how considering their natural succession. Generally, it is shown that the remaining natural peat swamp forests store huge above and below carbon volumes, even higher than in other peat swamp forests. The results highlight the uniqueness of the Biosphere Reserve and especially its importance in the worldwide efforts to reduce forest carbon emissions.

7.4 Sustainable Management Model of Peatland Ecosystem

We propose three ways to improve the current status: conservation and stopping further forest conversion, natural regeneration, and rehabilitation. The stopping of further forest conversion implies the need to designate boundaries and to enforce them. There is a conflict between the government and some villagers who wanted to utilize designated conservation areas. This conflict needs to be resolved through the preparation of a management plan that addresses both the integrity of the forest as well as the livelihoods of the villagers. Natural regeneration is an option for a faster recovery of forest vegetation after any disturbance. In the case of canopy species that could not be expected to undergo natural regeneration, some form of human-assisted regeneration is needed. Rehabilitation can target the areas that could undergo natural regeneration only with difficulty and would need human intervention such as planting.

We illustrate a logical framework for the activities conducted as well as the direction of actions to promote sustainable management of Giam Siak Kecil-Bukit Batu Biosphere Reserve (Fig. 7.4).

From the Fig. 7.4 the first level shows the different land cover types as well as their different levels of degradation without intervention, the natural forests could gradually convert into degraded or waste lands – as indicated by the dotted lines). As we have identified in each of the discussion sections above, these different land covers would need different management strategies. Ideally, the remaining natural forests should be conserved, the secondary forests allowed to regenerate and the degraded peat lands rehabilitated back into natural forests planted with endemic and economically valuable tree species, through agroforestry, or even as agriculture or plantation areas. Implementing these management strategies, however, is not easy. The strategies employed have to be based on paying attention to the reality that there are already villagers in the area who are dependent on the peat swamp forests for

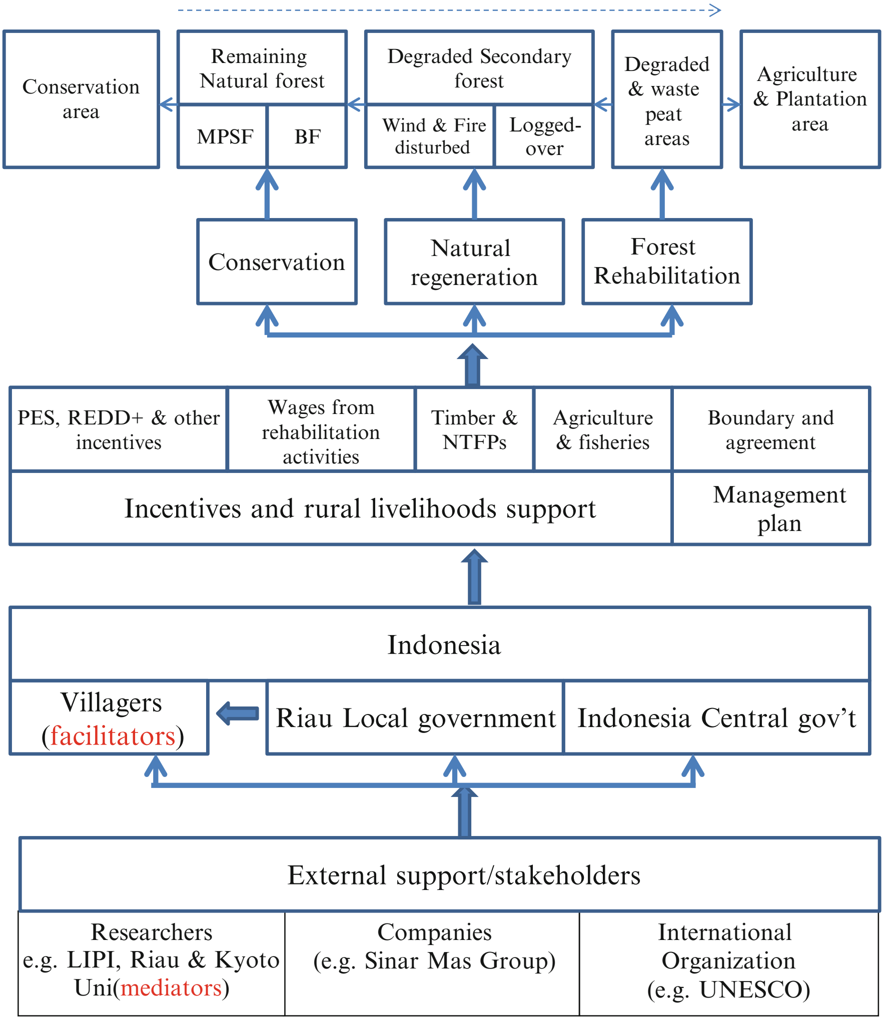

Fig. 7.4 A sustainable management model for the Biosphere Reserve

their livelihoods. Strategies, therefore, will need the participation of the villagers. In particular, an "interactive participation" by the local community is vital and here the villagers must have important roles in the decision-making and as well as they should be able to take a leading role in the activities. This will only be possible when strategies address not just the conservation or rehabilitation of the peat swamp forests but is especially addressing the needs of the livelihoods of the people living there.

We have made such consideration early in our rehabilitation activities with the planted tree species which have both economic value (i.e. timber and non-timber forest products) and ecosystem service value such as *Dyera lowii*, *Tetramerista glabra*, *Callophylum lowii*, *Palaquium sumatranum*, *Palaquium burckii*, *and Cratoxylon arborescens*. Placing stress on their potential to generate income from carbon storage and other ecosystem services, these trees can be cut and sold on the timber market, both on the international or the domestic market especially considering that there is a decreasing supply in timber given the increasing demand for building materials, furniture use or handicraft use because of strict controls on logging. Moreover, various non-timber forest products are provided by these different species such as the seeds of *Palaquium sumatranum* to produce oil for cooking, white latex from *Dyera lowii* and *Payena lerii*, and the bark of *Alseodaphne ceratoxylon* to be used as mosquito repellant.

It would be ideal if the above economically important but endemic tree species could be planted by the villagers themselves. However, the planting of these species is limited by the presence of other alternative tree crops such as rubber and oil palms. The wider planting of these species should then be supplemented by incentives in cash (i.e. wages paid for rehabilitation work) or in kind through the provision of other alternative livelihood strategies, or a combination of these. Financial incentives are especially important to induce people participation in rehabilitation efforts, in addition to the provision of information and technical assistance to communities about the species suitable for planting, their requirements in the restoration methods, and their market values.

As mentioned above, there is a current conflict between the villagers and the government since the declaration of the area into a conservation forests as access is now limited. A possible solution is the preparation of a development plan that is agreed upon by both villagers and local government wherein conservation, agroforest (rehabilitation with economic tree species and tree crops), and agricultural areas are designated. However, as was mentioned earlier, the villagers would also need to receive incentives not just from the rehabilitation but also from the forest conservation. There is also the possibility of some form of payment mechanism for the ecological services from peat swamp forests. These include funding mechanisms such as various Payments for Ecosystem Services (PES). In particular, we have discussed the possibility of tapping the newly proposed, although still being negotiated, the Reducing Emission from Forest Degradation and Deforestation (REDD+) mechanism.

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