Progress on Restoration Experiments of Degraded Peat swamp Forest Ecosystem In The Giam Siak Kecil-Bukit Batu Biosphere Reserve, Riau, Indonesia

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ABSTRACT

Restoration study was started on the earlier 2000 in Riau Biosphere Reserve. We concluded reasons that restoration should be important to be done in biosphere reserve; 1) large degraded peat-land and forest areas due to high fire intensity, poor canal drainage and illegal logging activities, 2) forest encroachment and conversion, 3) problem sustainable livelihoods for local communities and environmental services functions, and 4) the important rehabilitation of carbon sequestration and protection of remaining peat carbon stocks. We selected two different locations. First, forest degradation was caused by illegal logging activities and forest encroachment with extent 179,000 ha of totally core area and second, peat-land degradation due to severe fire yearly and poor water management in transition areas with extent 304,000 ha. The achievement indicators of restoration study are wildings and seed germination are better method to provide seedlings stocks. The vigorous regeneration performance of *Callophyllum lowii*, *Palaquium sumatranum* and some of sub storey tree species can be promoted to accelerate vegetation recovery processes in different forest types and degradation in the biosphere reserve. *Cratoxylon arborescens, Palaquium sumatranum, Callophyllum lowii* and *Tetromerista glabra* indicated promising species on vegetation rehabilitation efforts in the biosphere reserve shown by high survival rate ranges 57.14%-100%. Our results confirm that vegetation rehabilitation assisted by natural regeneration processes, has a great potential to sequester carbon in Bukit Batu Forest Block. Most of respondents or 94% of totally respondents are well perception on forest restoration. Forest values and restoration are important for them. In future detailed plan of restoration is important to be discussed, i.e. how to promote institutional framework collaboration, local community involvement and economic incentive, and carbon payment mechanism under REDD+ schemes or other sources of innovative financial mechanism such as the Global Peat-land Fund (GPF). Restoration is still going on; transplanting seedlings, tree growth, biomass and carbon increment monitoring, and establishing more canal block will be done in next field study.

Key words: Biosphere reserve, peat swamp forest degradation, REDD+ schemes, restoration.

INTRODUCTION

Peat-lands is one of the major land types in South East Asia which covers approximately 25 to 35 Mha. They mainly distributed in the region of Indonesia, Malaysia, Brunei Darussalam, Thailand and Viet Nam and smaller areas in Myanmar, Lao PDR and the Philippines (Page *et al.*, 2008, 2011, http://www.aseanpeat.net). Although originally largely forested, this habitat has been severely degraded since the 1980s. Deforestation of tropical peatswamp forest was estimated 3 Mha or less than 18 % of totally peat swamp forest area in Indonesia (Noor and Suryadiputra, 2004).

Peatswamp forests ecosystem play a critical role in the economy and ecology of the region-providing timber and non-timber forest products, water supply, flood control and many other benefits. They also play a very significant role of global significance in storing an estimated 50.4 Gt of carbon or equivalent of 96.6% of the global tropical peat C store (Page *et al*., 2008, 2011, http://www.aseanpeat.net).

Peatland in Indonesia mainly distributed in Sumatra (4.7–9.7 Mha), Kalimantan (3.1–6.3 Mha), and Irian Jaya (8.9 Mha) (Silvius, 1989, Rieley *et al*., 1996a). The largest peat-swamp forest ecosystem among the major forest formations in Sumatra are in Riau province. They still remained on the five large blocks of natural peat swamp ecosystem which in large 4.04 Mha or about 51 % of totally area of this province. In order to improve sustainability management of Riau's peat-land, one of the large remaining peat-land area, is about 698.663 ha of totally area, has been declared as Biosphere Reserve in 2009. This biosphere reserve will be used to conserve the peat swamp forest ecosystem, lakes, and other water systems in 178,722 ha of forest and peat land, which has been converted into industrial forest, plantation, agriculture, and residences (Jarvie *et al*., 2003, MAB Indonesia, 2008).

Recently, peat-swamp forest of the biosphere reserve has been degraded at an alarming rate; the ongoing development of large areas of peat-land as timber estates and palm oil plantations on a landscape scale constitutes a serious threat to peat-swamp forest ecosystem. A large area of the buffer zone had been developed as an industrial timber estate (195,259 ha or 88 %) and production forest (27,167 ha or 12 %), while the development of peat-land area in transition zone focused on palm oil plantations, agriculture, and housing (304,123 ha) and industrial timber estate (5,665 ha) (MAB Indonesia, 2008). Furthermore remaining peat-swamp forest in core area of biosphere reserve, the Bukit Batu Wildlife Reserve, was subject on illegal logging activities. Trees species of *Shorea* spp., *Tetramerista. glabra*, *Gonystylus. bancanus*, *Palaquium sumatranum*, *Palaquium burckii*, *Durio acutifolius*, and *Kompasia. malaccensis* was cut selectively during in 1999 to 2009. The logging activities decreased since 2005 and almost stopped completely by the beginning of 2010 in main river basin of Bukit Batu river.

Whilst remaining wind-disturbed *bintangur* forest and burnt *bintangur* forest areas are surrounded by an acacia timber plantation in buffer zone of biosphere reserve. The forest company allocated the area as a forest conservation area. Unfortunately, since 2000, migrant's people have logged illegally. First, they cut selectively the forest stands, while looking for suitable land for planting oil palm and establishing a settlement. In 2005, a large peat swamp forest area burned and even burned yearly. A large area became more open, enabling wind to attack the forest stands. The forest stand was getting worst condition. Currently, the area is easily accessed, and the population of the village has increased drastically since 2008.

In the other side of biosphere reserve, degradation of peat-land areas has mainly occurred due to drainage, followed by subsequent fires, as case in Tanjung Leban Village. The impacts of peat fire are estimated to have released over 400 million tones of CO_2 in totally peat-land areas in Indonesia. A recent report indicated that six of seven persistent fire prone zones in Sumatra which burned in 1997-1998 (Anderson and Bowen 2000). Severe fires on converted peat-lands in Riau occur yearly as well.

The restoration may be recommended when an ecosystem has been altered to such an extent that it can no longer self-correct or self-renew. The term *"restoration"* has been adopted to specifically mean any process that aims to return a system to a pre-disturbance condition (whether or not this way pristine) and includes *"natural restoration"* or *"recover"* following basic principles of secondary succession (Lewis, 1990). Ecological restoration is another important term and has been defined by the Society for Ecological Restoration (SER, 2004) as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. The goal of this process is to emulate the structure, functioning, diversity and dynamics of the specified ecosystem using reference ecosystem as models. Restoration attempts to revive the natural resource functions of degraded ecosystems, thus reinstating the environmental and economic services that these provide. The different option for improvement of degraded ecosystem can be expressed in terms of the two major characteristics of structure and function (Figure 1).

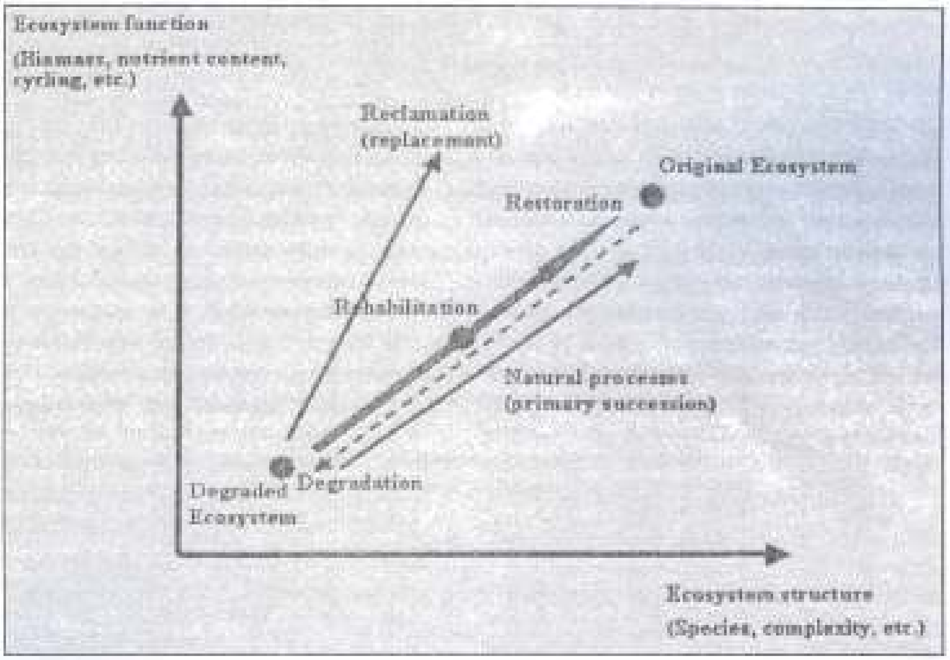


Figure 1. The different option for improvement of degraded ecosystem (Perrow *et al.*, 2002)

When degradation is occurs both characteristics of ecosystem structure and ecosystem function are usually reduced, although not necessarily equally. Used in its narrow sense, restoration implies bringing back the ecosystem to its original or previous state in terms of both structure and function. There are then a number of other alternatives, including rehabilitation in which this is not totally achieved, and replacement of the original by something different. All of these alternatives are covered, by many people, by the general term reclamation, mitigation is a different consideration (Perrow *et al.*, 2002).

Rehabilitation study on peat-lands in Central Kalimantan, carried out under the LIPI – JSPS Core University Program focused on the rehabilitation of intensively disturbed peat swamp forest areas (Takahashi *et al.*, 2001). Activities include trial planting of 0.75ha of disturbed PSF under different regimes (with and without clearing, fertilizer application, and mounds) and with different species (*Shorea balangeran*, *Shorea pinanga*, *Shorea seminis*, *Peronema canescens*, *Palaquium* sp.), and observations on natural regeneration in a fixed sample plot of 50 m² affected by wildfire, compared with a non-affected reference plot of 100m². Trials indicate that *Shorea balangeran* and *Palaquium* are best suited for replanting, as they have considerably higher survival rates (65-100 %) compared to the other species (6-65 %), and this seems irrespective of preparation techniques. Also, both species appear to be suited to heavily disturbed areas affected by repeated fires (Giesen, 2004). Rehabilitation of the mega rice project in Borneo (described by Dohong, 2008) has aims to restore and conserve 80 % of the former mega rice area. Rehabilitation involves restoration of hydrology through dam construction, blocking of the canals that were built to drain the peat-lands, followed by replanting with indigenous species of commercial value (such as *Dyera lowii*, *Alstonia pneumatophora*, and *Garcinia* spp. which produce latex that is used in chewing gum).

In Jambi enrichment line planting of secondary shrub was carried out using *Dyera lowii*, *Gonystylus bancanus* and *Endospermum diadenum* (Muus, 1996). Survival rates have been high on the whole more than 90%, and growth has been rapid: an average girth increment of more than 2 cm per year has been recorded. Restoration study also carried out in Riau (Gunawan *et al.*, 2007, 2008). Here they have found that regeneration of trees is constrained by the degree of disturbance (particularly with respect to hydrology), depth of peat, seed availability, predation of seeds and seedlings and also competition with other plant species. Where mother trees are still available and the hydrological regime conditions are not severely altered, then natural regeneration may be possible, but human intervention is required when disturbance is severe and seedlings and seed sources are scarce or absent. Gunawan *et al.* (2007, 2008) found that regeneration results in a dominance of secondary forest species tolerant of these factors, but many of the original canopy species (e.g. *Shorea* spp.) cannot regenerate under these conditions.

In case of biosphere reserve, we concluded reasons that restoration should be important to be done;

1. Large degraded peat-land and forest areas due to high fire intensity, poor canal drainage and illegal logging activities.
2. Forest encroachment and conversion.
3. Problem sustainable livelihoods for local communities and environmental services functions.
4. The important rehabilitation of carbon sequestration and protection of remaining peat carbon stocks.

This paper highlighted as following: 1) vegetation rehabilitation and restoration of hydrology, 2) promotion of sustainable livelihoods for local communities and ecosystem services, 3) rehabilitation of carbon sequestration and protection of remaining peat carbon stocks, 4) discussions for innovative financial mechanism, e.g. REDD+, other multi donor thrust fund, and private sector taxes (CSR, *Corporate Social Responsibility*).

Study Area

The study will be conducted in Riau Biosphere Reserve, Riau Province, Sumatra Indonesia. The Riau Biosphere Reserve is located in two districts, Bengkalis and Siak, and one city Dumai, in Riau, Sumatra Island, Indonesia. The total area is 698,663 ha, of which 75 % is covered by peat-land. The reserve is located between 0°44'–1°11'N and 0°11'–102°10'E. T uniqueness of this biosphere is that it is a vast landscape consisting of a unique hydrologi network of small lakes and streams and remaining natural peat swamp forest. The domina natural ecosystems are peat swamp forests surrounded by different types of land use, suc as production forests, degraded/abandoned lands, industrial plantations (timber and palr oil), agricultural lands, and settlements. Topographically, most of the terrain is at altitudes c 0–50 m above sea level. The climate is tropical and is influenced by the ocean, and the temperature averages between 26 °C and 32 °C. The rainy season is from September tc January, with rainfall of 804–4,078 mm/year. The dry season is from February to August (MAB Indonesia 2008).

The Giam Siak Kecil–Bukit Batu Biosphere Reserve is managed using a zoned approach. Three zones were implemented to promote the sustainable management of the peat swamp forest ecosystem, which consists of a 178,722 ha core area, a 222,426 ha buffer zone, and a 304,123 ha transition zone. The natural peat swamp forest remnant located in the core area consists of 84,967 ha in the Giam Siak Kecil Wildlife Reserve, 21,500 ha in the Bukit Batu Wildlife Reserve, and 72,255 ha in production forest allocated to forest conservation by the Sinar Mas Company. The function of the core area is to conserve biodiversity, the buffer zone functions to protect the core area, and the transition area functions as the outer and largest area of the biosphere reserve (MAB Indonesia, 2008).

To implement rehabilitation methods we will select two types of degraded peat swamp forest: (1) moderately degraded of logged-over peat swamp forest located at a river basin of Bukit Batu River, in a core area of Riau Biosphere Reserve, and (2) severely degraded areas in Tanjung Leban Village in transition zone of Riau Biosphere Reserve. The exact geographical location of logged over forest is 01°23'24.4"N, 101°51'59.1"E and degraded areas is 01°38'9.81"N, 101°46'13.8"E. For this paper will be focus on the progress report of rehabilitation study carried out in logged over forest in Bukit Batu forest block of Riau Biosphere Reserve (Figure 2).

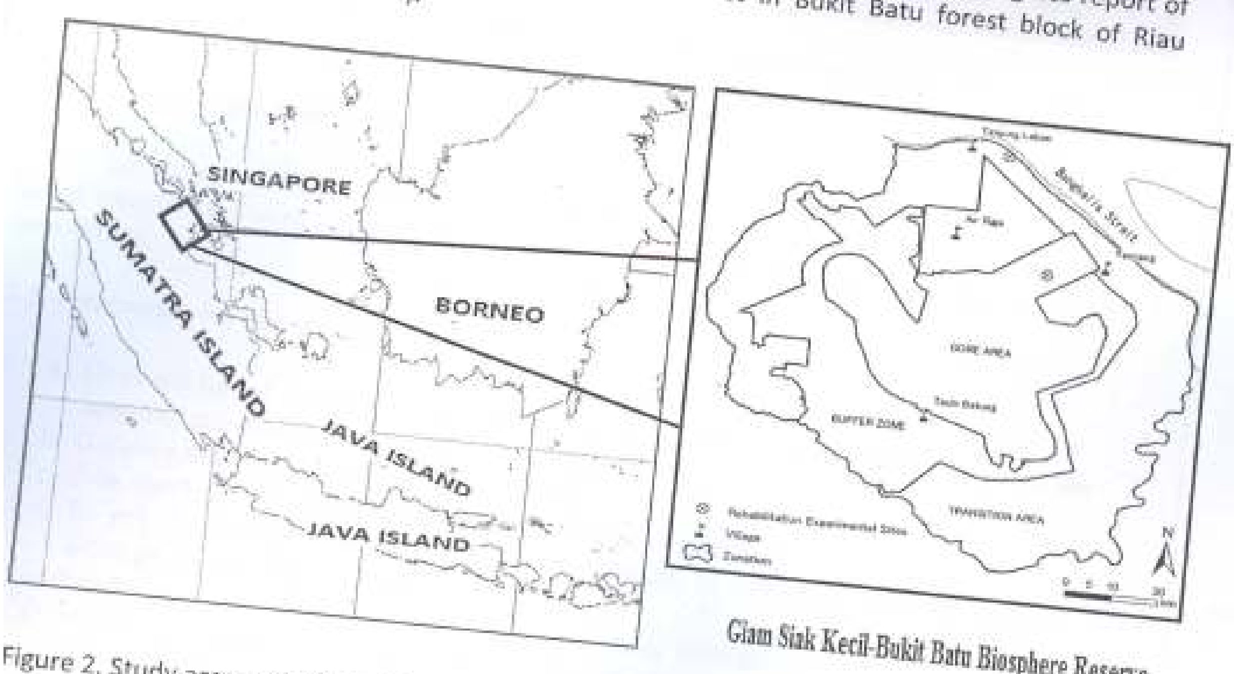


Figure 2. Study area and restoration experimental si...

METHODS

1. Production of Seedlings

Several techniques are employed for the production of seedlings stock including wildings, cuttings raised in the nursery and seeds germination methods. We constructed three distinct simple nursery from plastics and plastics net (Figure 3) related by necessity of seedling growth level.

The other treatment we also put wildings of some tree species on the forest floor directly after taking them (e.g. of *Palaquium sumatranum*-Balam, *Cratoxylon arborescens*-Geronggang, *Palaquium burckii*-Suntai and *Tetramerista glabra*-Punak). Production of seedlings to assure a continuous supply of seedlings for vegetation rehabilitation.

Figure 3. Simple nursery and several methods for producing seedlings stock

2. Method of Vegetation Rehabilitation

Enrichment planting methods were developed on areas where seeds or seedlings of target tree species were lacking. Line and gap planting method is commonly used in logged over forest.

2.1. Treatments for line planting:

a. Lines will be set on the west-east direction with width determined in relation to the height of sub-storey (e.g. 5, and 10 m); (Figure 4).
b. Distance between lines will be 5-10 m; and
c. Tree species in the area has been selected for transplanting.
d. To get the seedling we use some of techniques as following: cuttings methods, wildings, and seed germination.
e. Totally experimental area is 7 line planting covered 3500 m^2.
f. Totally two typical canopy tree species of peat swamp forest planted (e.g. *Callophylum lowii and Palaquium sumatranum*).

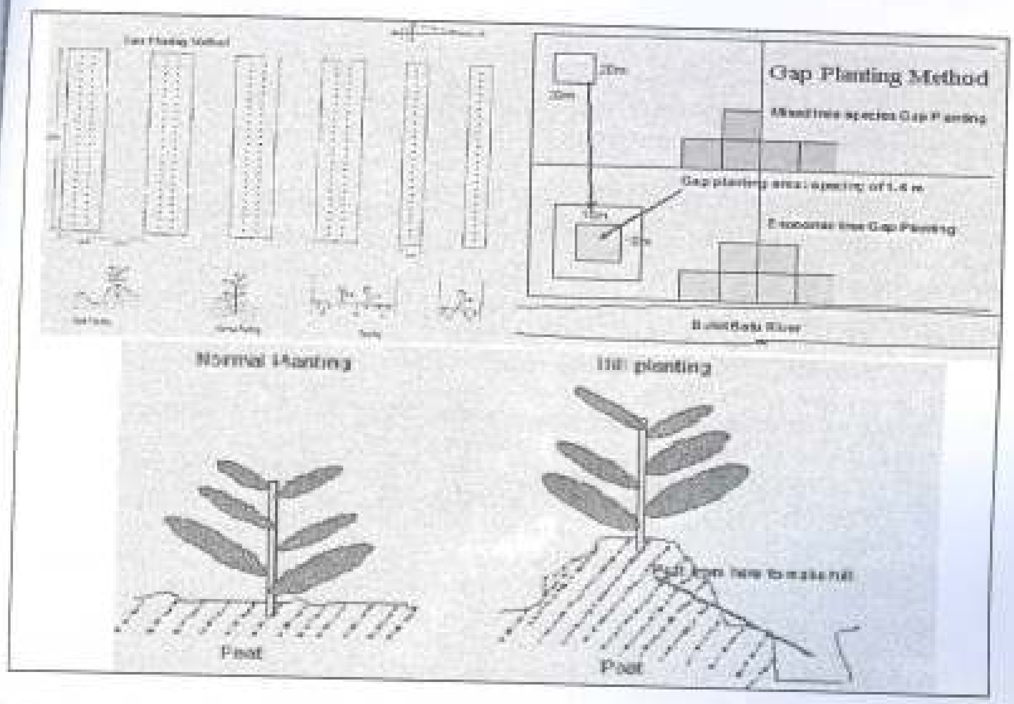


Figure 4. Rehabilitation Experimental methods (Kobayashi, 2010).

2.2. Treatments to be taken for gap planting:

a. Gap size will be 10 m x 10 m.
b. Totally 25 economical gap planting of *Dyera lowii* has been tried.
c. Totally 6 mixed gap planting of mixing tree species has been tried (e.g. *Dyera lowii, Palaquium sumatranum, Palaquium burckii, Callophyllum lowii, Cratoxylon arboresecens*, and *Tetrameristra glabra*)
d. Tree species suitable for the site condition will be selected. Wildings has been be applied (Figure 4).

The following lands of planting methods were applied at these location are normal and hill planting methods (Figure 4).

a. Normal planting method; a hole in the peat is dug and seedlings are planted in this hole.
b. Hill planting method; the peat soil is accumulated as a Hill and the seedlings are planted on this hill.

All of planted seedlings are monitored to determine the survival rate, height and their growth. The Survival rate is determined by formula:

$$\frac{\text{Number of alive species}}{\text{Total number of species}} \times 100$$

c. Local Community Perception and Participation

We carried out an interview using questionnaires for 36 households of local community of Temiang's village. Open indeed interview method used. We classified respondents to become four group as following: ten households who work inside forest area as fisherman, nine households who works on inside and border of conservation area as rubber farmer, nine households who work as village officer, three households who are informal leader, three households who are common villagers, and four households who are representative of KMPH (Conservation Group of Temiang's Forest Communities).

Percentage participation will be measured by formula Daniel (2002):

$$P(\%) = \frac{ni}{N} \times 100\%$$

Where: P = Percentage participation
ni= Number of respondents on category i meaning that high participation >66 %, moderate 33-66 %, and low participation < 33 %.
N = Total number of respondents

d. Plot Design

To study natural regeneration, we laid 144 plots of 2 × 2 m quadrates in different degradation and forest types in logged over forest, wind disturbed forest, and burnt forest. Five plots of 10 x 10 m for biomass and carbon plot monitoring between restoration experimental sites in Bukit Batu forest block. The tree species (DBH≤10cm for assessing regeneration and DBH≥3cm for biomass and carbon estimation) and number of stems were counted.

RESULTS AND DISCUSSIONS

1. Seedlings Production

The percentage of survival rate range 41% to 100% by using wilding method. The wilding method indicated that is the better way to produce seedling stock for some species which has problem in seed sources production. Tree species of *Cratoxylon arborescens, Vatica rassak, Madhuca motleyana,* and *Xylophia ferruginea* was highest of their survival rate (100%), followed by *Palaquium sumatranum* and *Tetramerista glabra* are survival rate of 92% and 88%. The lowest of survival rate was seedlings of *Palaquium burckii* (41%). The results show that wildings method can be used to produce seedlings stock on rehabilitation of degraded peat swamp forest areas. Even though increasing survival rate of *Tetramerista glabra* and *Palaquium burckii* have to put seedlings in the forest floor on the first step, before put into nursery (Table 1).

Table 1. Survival rate of seedlings stock started in June 2010

Family	Species	Number of seedlings surveyed	Survival rate of seedlings stock method			Survival Level
			Wildings (%)	Cuttings (%)	Seeds (%)	
Thecaceae	*Tetramerista glabra*	51	88	34	-	High and Low
Dipterocarpaceae	*Shorea spp*	115	-	11	-	Low
Dipterocarpaceae	*Vatica rassak*	7	100	-	-	High
Clusiaceae	*Callophyllum lowii*	547	-	-	96	High
	Cratoxylum arborescens	34	100	-	-	High
Sapotaceae	*Palaquium sumatranum*	493	92	-	-	High
	Palaquium burckii	109	41	-	-	Moderate
	Madhuca motleyana	11	100	-	-	High
Tymeliaceae	*Gonystylus bancanus*	314	-	7.5	-	Low
Moraceae	*Paratocarpus triandra*	33	-	-	100	High
Annonaceae	*Xylopia ferruginea*	9	100	-	-	High

The other method to produce seedlings stock tried is cutting method. Survival rate of seedling from this method is still low range 7.5% to 34%. The highest survival rate is *Tetramerista glabra* (34%), followed by *Shorea* spp (11%), and the lowest is *Gonystylus bancanus* (7.5%). The causes of low survival rate using cutting method identified as following: (1) size of branch used, (2) need to be transported seedling which has indication growth to plastic net nursery, (3) need to be frequently monitored during three month after cuttings. From these experiences the appropriate nursery for first stage seedling growth and frequently monitoring is important to increase the survival rate of seedling by using cutting method. In addition using such as kind a growth hormone will be useful as well.

The production of seedlings stock for rehabilitation efforts can use seed germination method. The high percentage of survival rate from seed germination method is ranging 96 % -100%, especially for tree species which has many seeds production such as trees of *Callophylum lowii* and *Paratocarpus triando*. We can collect seeds of *Callophylum lowii* (*bintangur*) in every July yearly. *Bintangur* seeds are found on the forest floor and germinated easily after 5 days (Figure 3). The combination seedling stock method used to rehabilitate degraded forest areas is important to get more success in supply of seedlings.

Furthermore rehabilitation of degraded forest area needs to consider the suitable species which can grow well in their habitat. Peat swamp forest is a unique ecosystem and need specific requirement for tree growth and survives. The extreme acid, poor nutrient and waterlogged condition should be considered for selecting trees species tried in degraded forest sites. In other hand peat-swamp forest rehabilitation activities need to provide seedlings and nursery improved. The village nursery and forest nursery should be developed their capacity and maintained. Training and technical assistance to local people are as promotion efforts to local community participation and creating economic incentive. The restoration project can buy seedlings and also involved them on the action program in future.

2. Vegetation Recovery Processes

a) Natural regeneration

Natural regeneration is a method of forest rehabilitation which exploits the natural processes of vegetation recovery. We selected six main upper-story tree species regeneration (Table 2). Those species formed main vegetation community on peat-swamp forest ecosystem. *Calophyllum lowii* Hook F had the highest regeneration performance in the wind-disturbed forest plots, decreased in the logged-over and burnt forest plots. Regeneration of this species is limited and even no regeneration in plot 2 and plot 3 in logged over forest.

Table 2. Regeneration performance of six main upper-story peat swamp forest trees

Species	Family	Number of stems (DBH < 10 cm)									
		LOF*			WDF†					BF‡	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Calophyllum lowii Hook F	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 Dyer	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

Note: * logged-over forest, † wind-disturbed forest, ‡ burnt forest

The great regeneration performance was *Palaquium sumatranum* in plots 2 and 3 of the logged-over forest, while it was rare in the other forest plots. This shows that distinct forest formation types occur in logged-over, wind-disturbed, and burnt forests, as the logged-over forest was classified as a mixed peat swamp forest and the wind-disturbed forest as a bintangur forest. The other upper-story tree species showed limited or no regeneration in each of the observed forest plots.

A difference is seen for some typical understory trees (Table 3). *Eugenia paludosa* King and *Eugenia setosa* King showed vigorous regeneration in almost all of the forest plots, followed by *Ilex macrophylla*, *D. hermaphroditica*, and *Mangifera longipetiolata*. The number stems was greatest in the family Myrtaceae, implying that the Myrtaceae regenerate readily after any disturbance. *Eugenia paludosa* King and *E. setosa* King of the family Myrtaceae and *D. hermaphroditica* of the family Ebenaceae were the most promising species in efforts to restore degraded peat swamp forest areas in Giam Siak Kecil–Bukit Batu Biosphere Reserve due to their high regeneration potential.

Table 3. Regeneration performance of some typical peat swamp forest understory trees

Species	Family	Number of stems (DBH < 10 cm)									
		LOF*			WDF*					BF[¹]	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Diospyros hermaphroditica	Ebenaceae	11	2	3	19	2	3	0	2	0	7
Eugenia paludosa King	Myrtaceae	13	10	13	15	18	11	17	7	0	9
Ilex macrophylla	Aquifoliaceae	0	5	11	4	0	6	20	20	0	1
Eugenia setosa King	Myrtaceae	24	23	7	14	17	2	3	2	0	3
Mangifera longipetiolata	Anacardiaceae	0	3	4	6	16	17	58	33	1	4

Note: * logged-over forest, * wind-disturbed forest, [¹] burnt forest

There are differences of dominance species composition and abundance on regeneration processes after any disturbance (Figure 5).

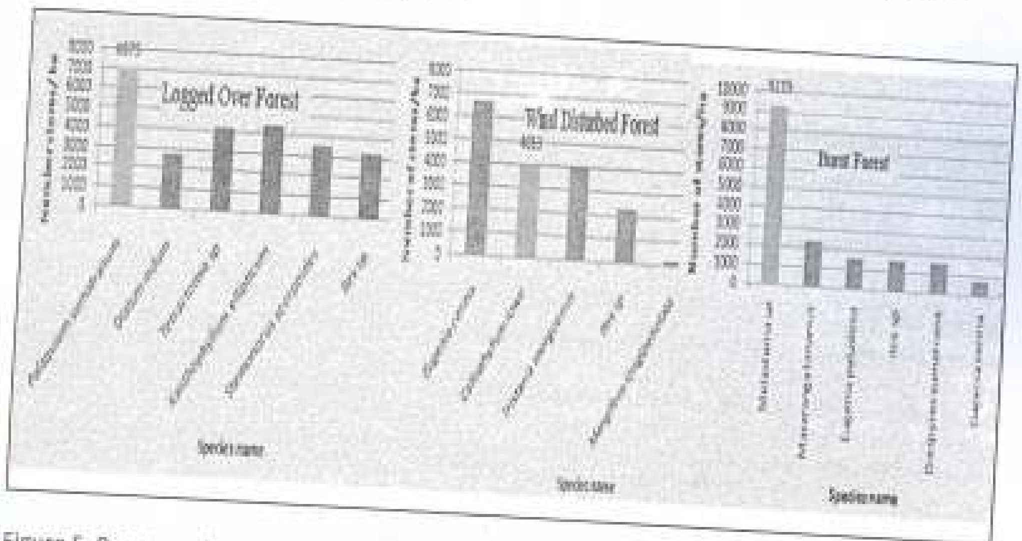


Figure 5. Regeneration performance of dominance species in different forest degradation

The most dominance and abundance species of the initial vegetation recovery was dominated by *Paloquium sumatranum* in logged over forest, followed *Dialum indum*, and other sub storey tree species. The results indicate that most of typical canopy species has problem with their initial regeneration after any disturbance. In wind disturbed forest show similar results that the dominance species composition and abundance are sub storey species. However typical canopy species of [illegible] in other hand it almost of dominance species composition of sub storey species become gregarious after repeated burning, especially pioneer species of *Melastoma* spp.

Regeneration is key to the existence of species in a community. It is also a critical component of forest management because regeneration maintains the desired species composition and stocking after biotic and *abiotic* disturbances (Khumbongmayum *et al.*, 2005). The natural regeneration of the peat swamp forest ecosystem is influenced by the interrelationships among peat subsidence, surface flooding during the wet season, and vegetation succession (Page *et al.*, 2008).

Kobayashi (1998) classified the initial vegetation recovery into shrub, herb, fern and climber types. Shrubs and herbs are considered facilitators, while ferns and climbers are competitors during secondary succession. The upper-story species *Palaquium sumatranum* regenerates well in logged-over forest, while *Callophylum lowii* regenerated vigorously in the wind-disturbed forest. *Palaquium sumatranum* and *Callophylum lowii* are important upper-story species in the Sumatran peat swamp forest vegetation community. Therefore, the regeneration of these species should promote similar species dominance in disturbed forest areas in the future. The comparison of the logged-over and natural forest plots indicated that *Palaquium sumatranum* is a dominant species for reestablishing a mixed peat-swamp forest. In addition, *Callophylum lowii* had started to regenerate in the wind-disturbed forest. The bintangur forest should persist in the biosphere reserve, without further disturbance. In contrast, *Callophylum lowii* regeneration was absent in the burnt forest, which the pioneer *Melastoma* spp. colonized quickly after the fire. Once the burnt forest was close to the wind-disturbed forest, which was a source of *Callophylum lowii* seeds, the regeneration of *Callophylum lowii* would be easier in the future. Nevertheless, most of the upper-story species have problems on their regeneration performance. Therefore, some form of human-assisted regeneration is needed. We carried out enrichment planting methods to accelerate regeneration of typical canopy species in Bukit Batu forest block.

1. Vegetation rehabilitation

The vegetation rehabilitation was applied in logged over forest areas in the firstly step. The survival rates of the seedlings at the rehabilitated sites and applied on varying rehabilitation techniques are shown in Table 4. In general, survival is high ranging 57.14 % to 100 % after five months of planting in all tried rehabilitation techniques. The highest tree species survival of normal-gap planting was *Palaquium burckii* and *Cratoxylon arborescens* with about 100 % survival, and then followed by *Tetramerista glabra* with 96.2 % survival. The lowest of survival was *Dyera lowii* with 69.1 % survival from a total of 450 tree species.

Five months after trying a gap-hill planting method showed high survival rate in all of tried tree species range 75.3 % to 100 %. The species with the highest survival rates are *Palaquium sumatranum (*100 %*)* and *Cratoxylon arborescens* (100 %), followed by *Tetramerista glabra* (96.3 %) and *Palaquium burckii* (88.2 %) respectively. The lowest survival rate was *Dyera lowii* (75.3 %). Whilst the line-hill planting method the highest survival rate was *Palaquium sumatranum* and *Callophyllum lowii* with 100 % survival, then decreasing survival rate in line-normal planting method with about 74.19 % then 57.14 % survival respectively.

Table 4. Survival rate (%) of main typical canopy species of peat swamp forest, 5 months after planting

Species	Num of Tress	Survival Rate (%)				Height Increment (cm)		Diameter Increment (cm)	
		Gap Planting		Line Planting		Normal	Hill	Normal	Hill
		Normal	Hill	Normal	Hill				
Dyera lowii	900	69.1	75.3	-	-	4.4± 3.2	4.9± 3.2	0.3± 0.2	0.3± 0.2
T. Glabra	52	96.2	96.3	-	-	13.1± 7.9	15.1± 4.7	0.6± 0.2	0.7± 0.2
P. Surckii	32	100	88.2	-	-	10.8± 13.7	9.6 ± 9.8	0.5± 0.2	0.5 ± 0.2
P. Sumatranum	118	90.1	100	74.19	100	11.6+ 13.3 4.1± 4.7	6.9+11.3 4.6± 6.1	0.4+ 0.2 0.07± 0.08	0.3+ 0.1 0.04± 1.2
C. arborescens	12	100	100	-	-	44.7+ 28.8	34.4+ 19.0	0.8+ 0.16	0.7+ 0.2
C.lowii	75	-	-	57.14	100	3.9± 3.3	10.8± 7.8	0.06± 0.05	0.09± 0.09

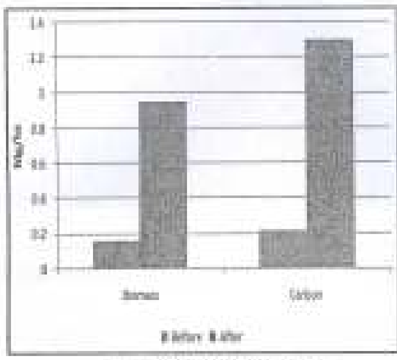
In general hill planting method is better method than normal planting methods are shown high survival rate of planted tress. A number of factors have been identified as causes of mortality of tress. In the early establishment, some of seedling died due to wetter of peat-land. The seedling for the first stage can't be adaptive in wet situation. The other factors the seedlings are still small to transplant on the field, such as seedlings of *Callophylum lowii*. The insect also was caused seedling of *Dyera lowii* died.

The average height and diameter increment from October 2010 till April 2011 are shown in Table 4 above. The highest growth performance is *Cratoxylon arborescens* with mean of height increment by normal planting 44.7 ± 28.8, hill planting 34.4 ± 14.0, and diameter increment by normal planting 0.8 ± 0.16, hill planting 0.7 ± 0.21. Followed by *Tetramerista glabra* with mean of height increment by normal planting 13.1 ± 7.94, hill planting 15.1 ± 4.68, and diameter increment by normal planting 0.6 ± 0.2, hill planting 0.7 ± 0.2 Seedlings from this species showed a higher survival rate (97 %) than its wildlings (61 %) (Figure 5).

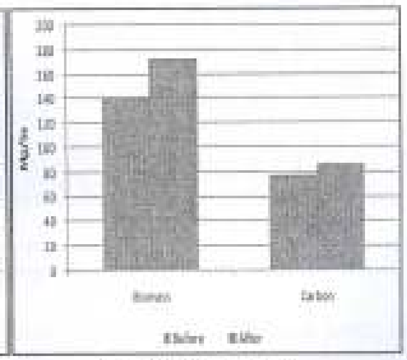
Figure 5. High performance of *Cratoxylon arborescens* and *Tetramerista glabra*)

2. Total increment of above biomass and carbon content

Total amount of above biomass and carbon content are getting increasing during five months restoration done. Biomass of 0.16 Mg/ha to 0.95 Mg/ha, and carbon content of 0.22 Mg/ha to 1.3 Mg/ha in experimental sites. Whilst in the reference sites are biomass of 140.7 Mg/ha to 173 Mg/ha and carbon content of 78.2 Mg/ha to 86.7 Mg/ha. Restoration can promote the increasing of total biomass percentage is 9.16% and total carbon content 8.45% either by human intervention or natural regeneration processes (Figure 6). The vegetation recovery has contributed of total above carbon sequestration are 327,481Mg/ha/years.



a. Experimental sites



b. Reference sites

Figure 6. Estimation above ground biomass and carbon content

In this research, the effect of vegetation rehabilitation through different method of restoration on the sequestration of carbon was studied. Our results showed that carbon increment was higher in forested areas or reference sites of 8.5 Mg/ha than in experimental site of 1.28 Mg/ha indicating that vegetation rehabilitation by natural regeneration processes have great potency to enhance carbon content in forest ecosystem restoration efforts. Even though this trend results still need to be measured and monitored after several year restoration done. Carbon sequestration from vegetation restoration is time dependent as carbon storage increases very quickly in vegetation at the beginning of vegetation restoration but gradually reaches a stable state. Therefore, the potential role of forestry in carbon sequestration in the long term should be linked to actions toward forest management to maximize fixation of CO_2 to balance CO_2 emissions. Besides reforestation, controlling the source of CO_2 emissions should also be vital to C balance (Peng *et al.*, 2009).

3. Hydrology Restoration and Remaining Carbon Protection

We just started establishing the one simple block canal collaborated by local people in Tanjung Leban Village in July 2010. The water table sensor had been installed as well in this location. Increasing water table level of the canal becomes first our target (Figure 7). The objective of this study was to improve the water table level and reserve water for dry season, supporting vegetation rehabilitation, fire and remaining carbon protection.

Figure 7. Establishing simple block canal in Tanjung Leban Village.

Drainage and development of tropical peat-land for every purpose leads to severe hydrological changes and loss of stored carbon, mainly as CO_2 emissions to the atmosphere (Page *et al.*, 2002, Hooijer *et al.*, 2002). Restoration of peat-land hydrological function is, therefore, a key pre-requisite for the re-establishment neutral peat-land carbon balance and for the re-establishment of forest vegetation (Page *et al.*, 2008). Quantifying the rise in groundwater levels of hydrological restoration in peat-lands together with an estimation of the mitigation in CO_2 emissions caused by this rise, is important information to make greenhouse gas emission mitigations tradable under the voluntary carbon market or REDD (Reducing Emissions from Deforestation and Degradation) mechanism.

In developed peat, drainage depth is related to peat organic matter oxidation rates and peat subsidence (Wösten *et al.*, 1997; Furukawa *et al.*, 2005). On average 60 % of peat subsidence is caused by oxidation and 40% by irreversible drying or shrinkage of the peat (Wösten *et al.*, 1997). In a recent review it is estimated that an increase of drainage depth by 10 cm results in the emission of about 9 t CO_2 ha−1a−1 (Couwenberg *et al.*, 2009). Another severe consequence of drainage is the occurrence of peat fires. Under natural circumstances peat consists of 90% water and 10% plant matter and hardly ever burns. However, if the groundwater level falls below a critical threshold of – 40 cm, the dry peat surface becomes susceptible to fire (Takahashi *et al.*, 2003; Wösten *et al.*, 2008). Only by rewetting the peat can its hydrological function be restored, peat oxidation decreased and fire risk reduced (Page *et al.*, 2008). Key success of hydrological restoration through canal blocking is the involvement of local communities in planning and implementation (Page *et al*, 2008).

We estimate threats to carbon stocks in two locations of our experimental sites can be seen in Table 5.

Table 5. Estimation of threats to carbon stocks in the restoration experimental sites.

Threats	Location of Experimental Sites	
	Temiang Village	Tanjung Leban Village
Fire	low	High
Conversion/land use change	moderate	High
Logging	moderate	Moderate

Tanjung Leban village has higher threat to carbon stocks than in Temiang Village due to severe fire occurred yearly in this location.

4. Institutional Framework

Stakeholder participation at all levels should be arranged from the start of restoration project. We identified three important stake holders which have different functions for supporting restoration on biosphere reserve in the future. In the village they established the forest conservation community group (KMPH in Temiang Village, and KMLHG in Tanjung Leban Village). The others stakeholders which are important for involving and supporting more restoration efforts as following are local and central government, i.e. BBKSDA (Conservation Agency) Riau, BLH (Environmental Agency) and Forest Agency at Provincial and District level of Bengkalis and Siak District.

In case restoration of degraded peat swamp forest in South Sumatra done by Merang REDD Pilot Project (MRPP) (Rayan, 2010), they describe the roles and relationship of the Central Government policies on deforestation reduction and National Carbon Accounting System consist of:

1. Central Government:
   - Policy interventions to tackle drivers of deforestation and forest degradation
   - REDD regulations (REDD Guidelines and REDD Commission)
   - Methodology
   - Institutional (National Registry, distribution of incentives/responsibilities, capacity building, stakeholder communication, coordination among REDD institutions)
   - Analytical tasks
2. Provincial level stakeholders
   - Methodology
   - Institutional (capacity development, stakeholder communication, and coordination among REDD institutions)
   - Demonstration activities, voluntary carbon projects.
3. District level stakeholders
   - Methodology
   - Institutional (capacity development, stakeholder communication, coordination among REDD institutions)
   - Demonstration activities, voluntary carbon projects.
   - Project level stakeholders
   - Methodology
   - Institutional (capacity development, stakeholder communication, and coordination among REDD institutions)
   - Demonstration activities, voluntary carbon projects

5. Local Community Participation

Its almost totally two year research conducted, we invited some important local villager to join field work, for this period we used the Sundak Research Shelter to raise their awareness on conserving tropical peat swamp forest, and teach them on basic forest ecology study which can be useful for monitoring biomass, carbon and forest dynamics in near future. Such as kind of those activities is an important step for involving the villagers on managing natural resources in surrounding their village. In the other way we invited the Conservation Agency of Forestry Department (BBKSDA) Riau to visit the village, doing an interview, and discussion. The results are they established pilot project on conservation village model.

To achieve active community participation, capacity and competency, interventions as well as from related stakeholders are essential. Training (forestry techniques, appropriate agricultural technologies, public awareness, facilitation and provision of alternative income generating activities, as well as strengthening group institutional capacities are ongoing under Riau Conservation Agency (BBKSDA) of Village Conservation Model project started 2011. From this point raising awareness, strengthening local capacity building, and restoration activities are preliminary step for keeping ecological services and other economic incentive advantages from peat swamp forest ecosystem in biosphere reserve.

We carried out interview with people who live in near restoration experimental sites. For first step we interviewed villager in Temiang Village. We classified two respondents group related by their perception about rehabilitation study. The first group are 34 respondents or 94% of totally respondents having well perception on forest restoration shown on the high scoring and category level (Table 3).

Table 3. Perception and participation respondents on restoration logged over forest

No	Scoring (%)	Category	Number of respondents	Percentage of participation	Main reasons
1.	0-33	Low	0	0	-
2.	33.3-66.6	Moderate	2	5.6	1. Villager can't use the protected forest area to convert agricultural land, and to cut the tress. 2. Boundary between protected forest areas and village areas is unclear. 3. Forest rehabilitation can be started, but the priority is determining the boundary of protected forest. 4. The forest company has been determined boundary of protected forest areas without discussing or negotiating with local people.
3.	66.6-100	High	34	94.4	1. Forest rehabilitation will re-

					establishing tree species which has been lost due to illegal logging activities. 2. Forest will keep in natural condition. 3. The ecological function of forest will be recovered, such as clean river water, increasing fish stock, mitigate flood, preventing forest fire, and wildlife conservation purpose.

Most of them know the important of forest and restoration. They have reasons that forest restoration will re-establish tree species which has been lost. The forest restoration will keep in natural condition and improve the ecological function of the forest. The respondents realized that forest should be managed in better way, such as rehabilitation or restoration program. The high number of respondents who agree to rehabilitation degraded forest will help the similarity program will be done by Forestry Department in the future. The social aspect is very important within managing the program rehabilitation sustainably. The awareness of villagers is one of some important factors to increase or extend the rehabilitation of degraded forest areas in the future. However the other factors should be considered to establish restoration program largely in this areas, example determining mechanism of their participation and economy incentive for villagers. The rehabilitation processes need to be monitored longer-term for ecological and economic success (Chokkalingam. 2001; Kobayashi, 2007).

The second group is two persons who are fisherman, one of them are also village officer. They didn't understand what the meaning of forest restoration. Basically they think that forest is important, but after the area was declared in 1999 by Central Government, the access entering the area was limited. They can't cut trees for their building house and also restricted to open the forest to become agriculture land. The Temiang's village has long history in utilizing the area for their activities. In the field we still found the old of rubber jungle as marking for their land. The change political situation of central government where the area was not well managed in 2000 s, giving well opportunities for the people cut illegally trees, and then opens the is to plant rubber jungle. For this history they claim that they should participate in determining the management of protected forest in the future.

From the beginning restoration experiments done, local villagers could be involved by collecting seeds-wildings-cuttings, seedlings-nurseries maintenance, land preparation, and transplanting tree seedlings. They can get not only an economic incentive from those activities, but also knowledge and awareness for forest conservation efforts. In the near future local villagers can get more income from gathering latex of Jelutung trees (*Dyera lowii*), seeds of Balam trees (*Palaquium sumatranum*), and some of villagers can continue carry out carbon dynamic monitoring as local partners. The establishing such kind of those systems is well steps to promote innovative financial mechanism, and finally security of their sustainable livelihoods. In addition successful vegetation rehabilitation can be also used to minimize occurring conflict between forestry department (BBKSDA Riau) and local villagers in Bukit Batu conservation area. Even though, strengthening local institution as well as extending the capability of rehabilitation programs are strongly required to achieve whole purposes completely.

6. REDD+ and Its Implication on Restoration Experiment Payments.

In Biosphere Reserve, the core areas of Giam Siak Kecil and Bukit Batu peat swamp forest remnant is a promising location for a REDD pilot project due to the still relatively natural forest cover and the large below ground carbon storage in the peat soil due to mostly peat dept ap to 6 m. Potential investors identified, either non market based (in early process) or market based (in advanced process) determined and offered.

Large peat-land and forest degradation in biosphere reserve needs a great deal of restoration that requires international efforts. The majority of those peat-land areas is un-sufficient managed and likely to be eligible for REDD project activities. The priority to demonstration activities of REDD scheme may be designated in areas with low level of threat and high level of carbon density (Murdiyarso *et al.*, 2008). In case of biosphere reserve we purpose in Bukit Batu Conservation areas, and even possible in all of core area which extent are approximately 178,722 ha of totally areas. In the other hand the local government and company can optimize to restoration efforts in transition area of biosphere reserve by using local budget and CSR schemes. The further identified demonstration areas should consider the capacity of the stakeholders and also the typology of peat-land used in considering pilot project of REDD+Schemes (Murdiyarso *et al.*, 2008).

The financial support mechanism is seen as major concern to improve the restoration capacity in biosphere reserve. The variety of donors such as Netherlands, Norway, Australia, Germany and the World Bank have indicated interest to finance REDD pilot initiatives in Indonesia peat swamp forests and degraded peat-lands (Silvius *et al.*, 2008). REDD in forested peat-lands would offer multiple benefits from social, economic and environmental perspective. As vulnerable ecosystem with a huge carbon pools peat-lands have to be prioritized in terms of their contribution to the global budget and other ecosystem services, such as flood regulation and habitats for diverse flora and fauna (Murdiyarso *et al.*, 2008).

CONCLUSION

In this paper highlighted the progress on restoration study. Some indicators of restoration study are successful. The seedlings production already applied by various methods and had been transplanted for vegetation rehabilitation. Natural regeneration can be promoted to accelerate vegetation recovery processes in different forest types and degradation in the biosphere reserve. *Cratoxylon arborescens, Palaquium sumatranum, Callophyllum lowii* and *Tetramerista glabra* indicated promising species on vegetation rehabilitation efforts in the biosphere reserve shown by high survival rate ranges 57.14% - 100%. Our results confirm that vegetation rehabilitation assisted by natural regeneration processes, has a great potential to sequester carbon in Bukit Batu Forest Block. Most of respondents or 94% of totally respondents are well perception on forest restoration. Forest values and restoration are important for them.

We identified three important stake holders which have different functions for supporting restoration on biosphere reserve. In the village they established the forest conservation community group (KMPH in Temiang Village, and KMLHG in Tanjung Leban Village). The others stakeholders which are important for involving and supporting more restoration efforts the following are local and central government, i.e. BBKSDA (Conservation Agency) Riau, BLH (Environmental Agency) and Forest Agency at Provincial and District level of Bengkalis and Siak District.

The financial support mechanism is seen as major concern to improve the restoration capacity in biosphere reserve. In near future for continuously the restoration efforts of degraded peat land and forest areas requires wider stakeholder's involvement and improve the management strategy of Riau Biosphere Reserve that will be more attractive to invite variety donors. Detailed plan of restoration is important to be discussed, i.e. how to promote institutional framework collaboration, local community involvement and economic incentive, and carbon payment mechanism under REDD+ schemes or other sources of innovative financial mechanism such as the Global Peat-land Fund (GPF).

Acknowledgment

We wish to thank the Kyoto University Global COE program (E04) for its financial support. We thank the Jisedai Program 2009 of Global-COE Kyoto University, Japan, which supported the research, GCOE Initiative 3, Kyoto University, and all of their research members for their support during the stay in the field and in Japan, the Global Environment Research Fund (E-1002) of the Ministry of Environment, Japan, for financial support, the Mitsui & Co. Environment Fund 7-078 for providing the field equipment, the BBKSDA Forestry Department in Riau for permission to conduct the study, the Biology Department, particularly the Laboratory of Ecology, at Riau University, for providing field equipment, the Sinar Mas Forestry Group for supporting us in the field logistically, the villagers of Temiang and Tanjung Leban for their assistance in the forest, and the students from Riau University and Andalas University who helped collect the data.

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