ENHANCED PROCESSES OF NATURAL REGENERATION ON DEGRADED PEAT SWAMP FORESTS IN RIAU BIOSPHERE RESERVE, SUMATRA, INDONESIA

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ABSTRACTS

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. Study was carried out in Riau Biosphere Reserve in which around 75% of areas covered by peatland. Total sampling plot was 3 ha. We laid 144 subplot of 2x2 m for assessing natural regeneration in logged over forest and wind-burnt disturbed forest. *Palaquium sumatranum* and *Calophylum lowii* are both important upper-storey 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. Regeneration is very important for improving the condition of disturbed peat swamp forest areas in the Riau Biosphere Reserve, but natural regeneration will not be sufficient to restore the forest vegetation and conserve the associated biodiversity. Some form of human-assisted accelerated regeneration will be needed, such as restoring of typical canopy species that have problems with establishment. The preliminary results indicate that some species of *Cratoxylon arborescens, Palaquium sumatranum, Palaquium burckii*, and *Tetramerista glabra* were promising species for rehabilitating degraded peat swamp forest areas shown by high survival rates in the range of 73.3 to 100%. The greatest growth performance are *Cratoxylon arborescens*, then followed by *Tetramerista glabra*. Enhanced processes of natural regeneration by restoring degaraded peat swamp forest should promote ecosystem services (e.g. carbon sequestration potential and conservation) and rural livelihoods.

Key words: Biosphere reserve, peat swamp forest, regeneration.

INTRODUCTION

One of the serious problems in sustainably managing peat swamp forests is their current state of severe degradation. Compared to one with relatively good forest condition, these degraded forests need innovative rehabilitation activities. In the Biosphere Reserve, land conversion and poor management had caused the loss of around 300,000 ha of natural peat swamp forest within the past 17 years.

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 ceratoxylon* used as mosquito repellant. Other trees provide medicine and fruits. Nowadays, however, these forest products have gradually decreased with the deforestation and degradation of natural peat swamp forests. Moreover, 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 jungle rubber garden exist. 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 as forest degradation will continue.

In Riau Biosphere Reserve can be divided into two types of forest namely the mixed peat swamp forest (MPSF) and bintangur forest (BF). Furthermore, we classified the remaining peat swamp forests into natural forest and secondary forest where in the secondary forests consist of wind- and forest-disturbed forest and logged-over forests. This paper discusses the regeneration processes and progress of restoration experiment in the logged-over forest of mixed peat swamp forest. The objectives of this study are to enhance natural regeneration processes on degraded peat swamp forests and peatland areas, and to clarify the amount of carbon storage after ten months vegetation restoration done and by natural regeneration processes.

MATERIAL AND METHOD

The area of study is located at Riau Biosphere Reserve, Riau Province in the coastal east of Sumatra Island. Riau province covers an area of about 9 Mha. Having the largest peatland area in Sumatra. This biosphere is unique such that it has a vast landscape with unique hydrological network of small lakes and streams and still has remaining natural peat swamp forest. The dominant natural ecosystems are peat swamp forests surrounded by different types of land use, such as production forests, degraded/abandoned lands, industrial plantations (timber and oil palm), agricultural lands, and settlements.

In 2009–10, we carried out a survey of six permanent monitoring plots in each of 0.5 ha subplot in natural and disturbed forest - these were also intended for ecological studies. The total area of the plots was three ha. Three plots were located in natural peat swamp forest at 01°21'12.7"N, 101°47'22.7"E and 01°22'16.2"N, 101°46'23.1"E; and the remaining three plots were in logged-over peat swamp forest at 01°23'24.4"N, 101°51'59.1"E, wind-disturbed forest at 01°27'56.7"N, 101°40'49.8"N, and burnt forest at 01°27'46.6"N and 101°40'50.1"E (Figure 1). Within each of the monitoring plots, we established a 25×25 m sub-plot in which the DBH of all trees higher than or equal to (≥) 3 cm was recorded. To study natural regeneration, we laid out 144 of 2×2 m quadrats inside each of the 25×25m sub-plots (Figure 2). Within the quadrats, saplings of DBH≤10 cm were counted. Voucher specimens of plants were sent to the Ecology Laboratory of Riau University for identification and verified at the Herbarium Bogoriense in LIPI, Cibinong, Indonesia.

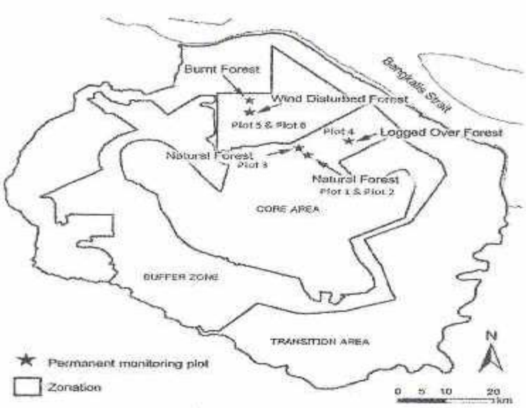

Fig 1. Permanent monitoring plots.

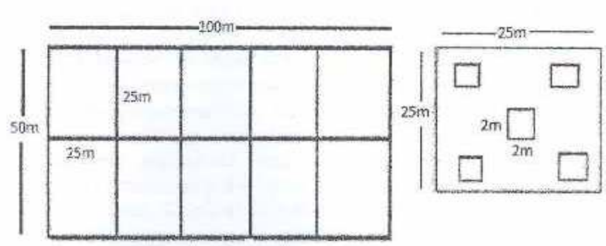

Fig 2. Plots Design

RESULTS AND DISCUSSION

Natural Regeneration Processes

The regeneration performance of six main upper-storey tree species was examined (Table 1). *Calophyllum lowii* has the highest regeneration performance in the wind-disturbed forest plots, but is less in the logged-over and burnt forest plots. It has no regeneration in sub-plots 2 and 3 in the logged-over forest or in sub-plot 9 of the burnt forest.

Table 1. Regeneration performance of six main upper-story peat swamp forest trees.

Species	Family	Number of stems (DBH < 10 cm)									
		Plot 4*			Plot 5†					Plot 6‡	
		Sub-plot			Sub-plot					Sub-plot	
		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

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

The best regeneration performance is shown by *Palaquium sumatranum* in sub-plots 2 and 3 in the logged-over forest, but is low in the other forest plots. This shows that distinct forest formation types occur in logged-over, wind-disturbed, and burnt forests.

Table 2. Regeneration performance of some typical peat swamp forest under storey trees.

Species	Family	Number of stems (DBH < 10 cm)									
		Plot 4*			Plot 5†					Plot 6‡	
		Sub-plot			Sub-plot					Sub-plot	
		1	2	3	4	5	6	7	8	9	10
Diospyros hermaphroditica	Ebenaceae	11	2	3	19	2	3	0	2	0	7
Eugenia paludosa	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	Myrtaceae	24	23	7	14	17	2	3	2	0	3
Mangifera longipetiolata	Anacardiaceae	0	3	4	6	16	17	58	33	1	4

* logged-over forest, * wind-disturbed forest, ‡ burnt forest

A significant difference is seen for some typical under-storey trees (Table 2). *Eugenia paludosa* and *Eugenia setosa* show vigorous regeneration in almost all of the plots, followed by *Ilex macrophylla*, *Diospyros hermaphroditica*, and *Mangifera longipetiolata*. The number of stems is highest in the *Myrtaceae*, implying that plants of this family regenerate readily after disturbance. These imply that *Eugenia paludosa* and *Eugenia setosa* of the Myrtaceae and *Diopyros hermaphroditica* of the Ebenaceae are the most promising nurse species in efforts to restore degraded peat swamp forest in Giam Siak Kecil–Bukit Batu Biosphere Reserve. One year after monitoring was done, the composition and regeneration performance did not change significantly (Table 3).

Meanwhile, *Calophyllum lowii* and *Palaquium sumatranum* changed in their number of stems. The other typical canopy tree species show limited and even no regeneration in some of sampling plots.

Table 3. Regeneration performance of six main upper-story peat swamp forest trees.

Species	Family	Number of stems (DBH < 10 cm)									
		Plot 4*			Plot 5†					Plot 6‡	
		Sub-plot			Sub-plot					Sub-plot	
		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

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

On the other hand, most of sub-storey species still kept on regenerating (Table 4). Most of species have shown good regeneration in all the plots studied, although some species had different performance in each plot. In the logged over forest in plot 4, the species with fastest regeneration was *Eugenia setosa*, followed by *Diosphyros hermaphroditica*. The same species and ranking were observed in the plot 5 and 6. In wind disturbed forest in plot 5 and plot 6, the species with vigorous regeneration was *Mangifera longipetiolata, followed by Ilex macrophylla*. Each of tree species regenerated had distinct distribution and abundance.

Table 4. Regeneration performance of some typical peat swamp forest understory trees.

Species	Family	Number of stems (DBH < 10 cm)									
		Plot 4*			Plot 5†					Plot 6‡	
		Sub-plot			Sub-plot					Sub-plot	
		1	2	3	4	5	6	7	8	9	10
Diospyros hermaphroditica	Ebenaceae	11	2	1	13	2	3	0	2	0	6
Eugenia paludosa	Myrtaceae	6	1	0	17	16	9	15	7	0	10
Ilex macrophylla	Aquifoliaceae	1	5	11	4	0	6	20	20	0	1
Eugenia setosa	Myrtaceae	20	21	0	12	15	2	2	2	0	3
Mangifera longipetiolata	Anacardiaceae	0	4	4	8	13	8	47	25	1	4

* logged-over forest, * wind-disturbed forest, ‡ burnt forest

The natural regeneration of the peat swamp forest ecosystem is influenced by the interrelationships between peat subsidence, surface flooding during the wet season, and vegetation succession (Page *et al.* 2008). In the wind-disturbed and burnt forests, the dominant regenerating species after any disturbance are the pioneer species *Eugenia cerina* and *Melastoma* spp. In burnt forest, the fern *Nephrolepis biserrata* quickly colonises the open land. Such species are competitors and facilitators in secondary succession (Kobayashi 1998). Gunawan *et al.* (2007) found that regeneration processes are influenced by disturbed reproductive trees in degraded greenbelt peat swamp forests where some secondary species showed vigorous regeneration, whilst most of the typical canopy species (*e.g. Shorea teysmaniana, Shorea uliginosa* and *Calophylum grandiflorum*) secondary succession. The upper-storey species *Palaquium sumatranum* regenerates well in logged-over forest, while *Calophylum lowii* starts to regenerate in wind-disturbed forest. *Palaquium sumatranum* and *Calophylum lowii* are both important upper-storey 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. Comparison of the logged-over and natural forest plots indicates that *Palaquium sumatranum* is a dominant species for re-establishing a MPSF while *Calophylum lowii* started to regenerate in the wind-disturbed forest. The BF should persist in the biosphere reserve in the absence of further disturbance. In contrast, the pioneer *Melastoma* sp. colonised the burnt forest quickly after fire and *Calophylum lowii* was absent. Regeneration of *Calophylum lowii* after burning may be easier since the burnt forest is close to the wind-disturbed forest, a source of *Calophylum lowii* seeds. Nevertheless, most of the upper-storey species have problems regenerating. Kobayashi (1998) found that the natural regeneration of dipterocarp species and ramin (*Gonystylus bancanus*) is very poor. Therefore, some form of human-assisted regeneration is needed to promote biodiversity in disturbed peat swamp forest, such as enrichment planting and accelerated regeneration (Kobayashi 1998).

Enhanced processes of natural regeneration by restoration experiments.

The restoration was applied in logged-over forest areas. The survival rates of the seedlings planted using hill planting and normal planting methods are presented in Figures 3 and 4. In general, the survival rate of seedlings decreased after ten month from being planted. The survival rate within five month ranged from 57.14% to 100%, and after ten month ranged from 51.4 to 100%. The species with the highest survival rate was *Palaquium burckii* and *Cratoxylon arborescens* with 100% survival in hill planting, followed by *Tetramerista glabra* ranging from 84.6% to 96.2%. The lowest of survival was observed for *Dyera lowii*, with 64.66% to 71.78%.

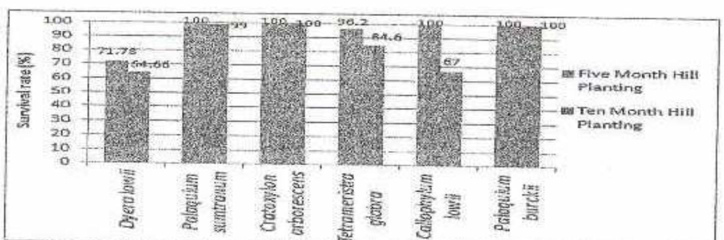

Fig 3. Survival rate (%) of tree species with hill planting method

In normal planting, species with highest survival were *Cratoxylon arborescens* with 100%, followed by *Palaquium sumatranum* ranging from 77.2% to 90.91%. *Calophyllum lowii* had the lowest survival rate of 52.38% to 57.14%.

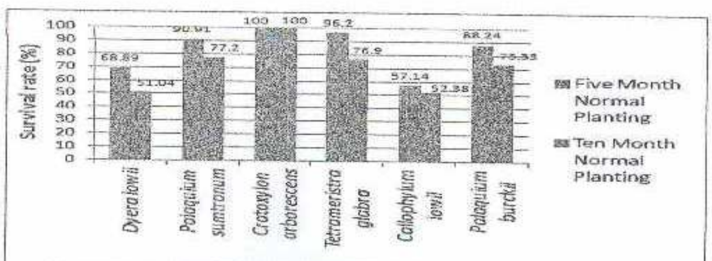

Fig 4. Survival rate (%) of tree species with normal planting method.

had limited or no regeneration.

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-storey species *Palaquium sumatranum* regenerates well in logged-over forest, while *Calophylum lowii* starts to regenerate in wind-disturbed forest. *Palaquium sumatranum* and *Calophylum lowii* are both important upper-storey 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. Comparison of the logged-over and natural forest plots indicates that *Palaquium sumatranum* is a dominant species for re-establishing a MPSF while *Calophylum lowii* started to regenerate in the wind-disturbed forest. The BF should persist in the biosphere reserve in the absence of further disturbance. In contrast, the pioneer *Melastoma* sp. colonised the burnt forest quickly after fire and *Calophylum lowii* was absent. Regeneration of *Calophylum lowii* after burning may be easier since the burnt forest is close to the wind-disturbed forest, a source of *Calophylum lowii* seeds. Nevertheless, most of the upper-storey species have problems regenerating. Kobayashi (1998) found that the natural regeneration of dipterocarp species and ramin (*Gonystylus bancanus*) is very poor. Therefore, some form of human-assisted regeneration is needed to promote biodiversity in disturbed peat swamp forest, such as enrichment planting and accelerated regeneration (Kobayashi 1998).

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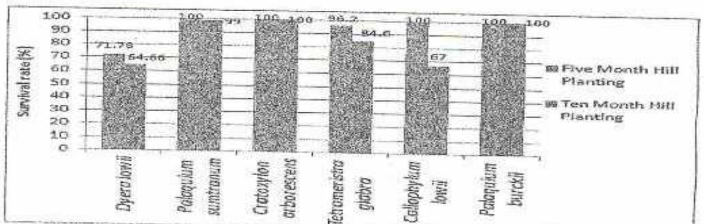

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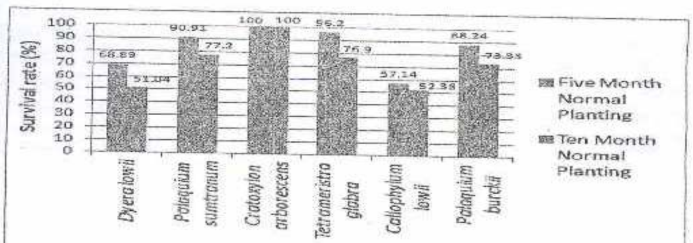

Fig 4. Survival rate (%) of tree species with normal planting method.

Hill planting method was observed to be better than normal planting as shown by the high survival rate of planted trees in the former. A number of factors have been identified to be the cause of tree mortality. In the early establishment, some of seedling died due to excessive water content of the peatland. For other species, the seedlings were still too small to be transplanted on the field, such as the seedlings of *Calophyllum lowii*. Insects also caused mortality for some seedlings of *Dyera lowii*.

The growth performance after ten month rehabilitation was presented in Table 5. Diameter and height increment in both hill and normal planting method were shown by positive correlation analysis (r). Hill planting was observed to be better method compare to normal planting but the opposite is true for *Tetramerista glabra* and *Palaquium buckii*. the tree species *Cratoxylon arborescens, Calophyllum lowii, Dyera lowii* and *Palaquium sumatranum* show average height increment in normal planting method. This result is similarly shown in the increasing diameter increment in hill planting compare to normal planting method.

Table 5. Growth performance of tree species after ten month

Species	Height Increment (cm)			Diameter Increment (cm)		
	Normal Planting	Hill Planting	Correlation (r) and t-paired test (α0.05)	Normal Planting	Hill Planting	Correlation (r) and T-Paired test (α0.05)
Tetramerista glabra	69.5±27.9	59.2±18.7	r=0.3; p=0.001	0.9±0.2	1.0±0.2	r=0.2; p=0.1
C. arborescens	122±42.0	144±49.0	r=0.7; p=0.4	1.0±0.1	1.2±0.2	r=0.5; p=0.09
Calophyllum lowii	16.6±6.08	35.2±8.7	r=0.1; p=0.2	0.1±0.05	0.2±0.1	r=0.2; p=0.2
Dyera lowii	22.3±19.2	23.5±20.8	r=0.2; p=0.3	0.6±0.4	0.7±0.5	r=0.2; p=0.03
P. sumatranum	14.8±11.3	19.2±15.8	r=0.2; p=0.4	0.3±0.1	0.3±0.9	r=0.4; p=0.06
Palaquium burckii	18.2±14.4	14.6±14.4	r=0.1; p=0.7	0.5±0.1	0.6±0.2	r=0.2; p=0.03

The highest diameter increment was observed for *Cratoxylon arborescens* with 1.2 cm ±0.2 by hill planting method, and 1.0 cm ±0.1 in normal planting method. This was followed by *Tetramerista glabra* with 1.0 cm±0.2 under hill planting and 0.9 cm±0.2 in normal planting method. The lowest diameter increment under both hill and normal planting method was observed for *Palaquium sumatranum*. Meanwhile, the tree species *Cratoxylon arborescens* and *Tetramerista glabra* have highest height increment in both planting methods. *Palaquium sumatranum* and *Palaquium burckii* had the lowest height increment in hill and normal planting, respectively. A T-paired test showed that growth performance of *Tetramerista glabra, Dyera lowii*, and *Palaquium sumatranum* were significantly different ($p<0.05$). Meanwhile, *Palaquium burckii, Calophyllum lowii* and *Cratoxylon arborescen* were not significantly different ($p>0.05$).

Biomass increased from 2.94 Kg ha^{-1} to 28.9 Kg ha^{-1}, and carbon storage increased from 1.55 kg C ha^{-1} to 14.5 kg C ha^{-1} in experimental sites. Carbon sequestered by vegetation rehabilitation increased from 3.77 Kg C ha^{-1} to 12.05 Kg C ha^{-1}.

These increases in biomass, carbon storage and carbon sequestration in forested areas by natural regeneration processes are sequestered 0.34 Mg C ha^{-1} carbon within ten months of monitoring. There was an increase in biomass from 3.88 Mg ha^{-1} to 4.57 Mg ha^{-1} and carbon storage of 1.94 Mg C ha^{-1} to 2.28 Mg ha^{-1}.

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