How to restore the Tropical Peat Swamp Forest in Aceh Province, Indonesia

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Abstract
This study aims to describe the condition of Tripa Peat Swamp Forest (TPSF) in the Province of Aceh Indonesia that has been converted from forest to oil palm plantation and mixed farms. The results showed that the degradation of the peat soil and the environment have occurred in the TPSF. Degradation of peat is characterized by the occurrence of changes in water holding capacity and changes in chemical and physical properties of soil. Environmental degradation is characterized by changes in groundwater levels and land subsidence. TPSF restoration efforts can be carried out in accordance with the directives of land use and land conservation and water management.
Key words: Land degradation, peat soil, conservation, water management

Introduction
Peatlands cover about 400 million hectares worldwide, representing about half of world's wetlands. Over 50 million hectares have been converted to intensive agriculture and forestry use and are degrading (Wetlands International, 2015). The total area of peatlands in Indonesia is estimated to 20.6 million hectares, or about 10.8 percent of Indonesia's land area. It is approximately 7.2 million hectares or 35% of it is located on the island of Sumatra (Wetlands International, 2014).

It is well known that sustainable management of agricultural peat soil rely on effective soil water management. Extensive drainage of UK lowland peat soil for agricultural production is considered a major contribution to the rate of degradation and the loss of peat resources (Kechavarzi *et al*, 2010). Similar cases on agricultural peatlands in Indonesia tend to be degraded due to extensive drainage constructed for palm oil plantation. Ritzema *et al* (2014) reported in 1990's the construction of thousands of kilometers of canals on million hectars of peatlands for agriculture in Central Kalimantan on the island of Borneo, Indonesia resulted in over-drainage and targets for agricultural production failed. This research was conducted in the area of Tripa Peat Swamp Area (TPSF) of 62,000 hectares in Aceh Province, Indonesia. Geographically the area located at 03^0 44'-03^0 56' NL and 96^0 23' - 96^0 46' EL. The TPSF has been degraded as a result of conversion of forest land into oil palm plantations and mixed farms. This paper describes the TPSF degraded condition and how to restore theTPSF.

Materials and Methods
The study consisted of two phases, the first is a degradation assessment (land and environment) of theTPSF and the second is how to restore it. Land degradation assessment based on some parameters of physical and chemical properties of soil/peat such as bulk density (BD), peat thickness, water holding capacity, soil moisture content, soil pH, and C-organic content. Assessment of environmental degradation based changes in groundwater levels and land subsidence. Furthermore, it also described the TPSF restoration efforts can be carried out in accordance with the directives of land use and land conservation and water management (canal blocking).

Results and Discussion
A. Degradation of the soil/peat and the environment
1. Degradation of the soil/peat
(a) *Change of water holding capacity*
Drying land through the construction of drainage channels may alter the ability of peat to absorb water. The longer the soil is dry or the longer the age of planting oil palm plantations will lower the water level in the peat land. This condition is caused by changes in the level of peat decomposition that occurs in the oil palm plantations. The ability to absorb and hold water of the peat depends on the level of maturity. The ability water holding capacity of fibric is greater than hemic and sapric, while hemic is greater than sapric (Sabiham, 2009).

Field observations showed that the conversion of forest land into agricultural land has been a change in the water holding capacity of peat due to the maturation of fibric into hemic to sapric. The more mature peat, the greater of BD. It ranged from 0.35 to 0.55 for hemic and 0.50-0.75 for sapric. This change followed by a decline in the water holding capacity of peat. Fibric can absorb water reached 2-3 times higher than hemic and sapric.

The reduced water holding capacity of peat is one aspect of peat soil degradation, but on the other hand it could be better assessed. The increasing value of BD will increase the soil bearing capacity (Agus, 2009). Thus it can be said that the change in mass of peat material from fibric to sapric, on the one hand can result in land degradation due to reduced water holding capacity but on the other hand gives a positive value as a medium for plant growth because of the increasing consolidation of peat.

(b) Change of chemical properties of soil/peat

Drained peat soils caused some changes in soil chemical properties. Table 1 shows the pH value of top soil varies between soil types. In general, the pH H_2O is between acid (5.07) to slightly acid (5.64) and for pH KCl ranged from 4.28 to 5.01 lower than pH H_2O. Soil pH value of Aluvial Eutric (Typic Tropofluvent) is slightly acid because it contains a lot of minerals. On peat soil types of Organosol Fibric (Typic Haplofibrist), Organosol Hemic (Typic Haplohemist) and Organosol Sapric (Typic Haplosaprist), soil pH relatively acid to very acid due to the land drying, there will be oxidation of some organic compounds that cause the release of some groups such as carboxylic acids. These groups form organic acids that cause the soil to become acidic. Some of these acids can also have negative effects on plants (Agus *et al.*, 2011). Furthermore, the results of measurements of pH H2O on almost all soil samples of topsoil have pH from 4.33 to 6.51. Likewise, the measurement sample at a depth of 60 to 80 cm, it is generally the pH value is above pH 4.5 and no one had the extreme pH or pH <3.50. This shows that there is no indication of danger pyrite for all of the soil profile in the survey area. The existence of pyrite indicated if pH H2O at a depth of 60-80 cm smaller or equal to pH 3.50.

Tabel 1. Values of chemical properties in various soil types of top soil (0-20 cm) in the TPSF

No	Soil types (SNI/USDA)	Chemical properties of soil/peat					
		pH (H_2O)	pH (KCl)	C-organic (%)	N-total (%)	C/N	Ash content (%)
1	Aluvial Eutric (Typic Tropofluvent)	5.64	5.01	3.28	0.24	13.67	4.52
2	Aluvial Distric (Typic Dystropepts)	5.54	5.07	3.65	0.18	20.28	4.32
3	Aluvial Gleic (Typic Tropaquent)	5.54	4.94	2.59	0.16	16.19	5.05
4	Organosol Fibric (Typic Haplofibrist)	5.15	4.68	45.21	1.42	31.84	2.19
5	Organosol Hemic (Typic Haplohemist)	5.07	4.51	47.50	1.77	26.83	3.42
6	Organosol Sapric (Typic Haplosaprist)	5.11	4.28	67.10	2.94	22.82	3.91

Source: Soil analyzed (2013)

(c) Change of physical properties of soil/peat.

The values of some physical properties of soil are presented in Table 2. The value of Bulk Density (BD) of mineral soil in the study area was generally higher than the value of BD of peat. BD value of the mineral soil ranged from 0.74 to 1.06 while BD of peat soil varied from 0.31 to 0.72. The lowest value of BD was found in Organosol Fibric (Typic Haplofibrist) with BD of 0.31-0.43, while in Organosol Hemic (Typic Haplohemist) and Organosol Sapric (Typic Haplosaprist) the value of BD is between 0.53 to 0.72. This shows that the conversion of peat swamp into dry land agricultural ecosystems will change in soil physical properties characterized by increased the BD of peat. From the aspect of agricultural land, improvement of BD and maturity peat is an indication of the change in the quality of peatland is getting better. Peatland with BD <0.5 or smaller is less suitable for agriculture, especially for perennial crops because of low soil bearing capacity. Field observations also showed that the sapric peat land, land consolidation has been going well so that the soil becomes more compact. Increasing the value of BD of peat soil will cause shrinkage of peat soil occur that will cause land subsidence.

Table 2. Values of physical properties in various soil types of top soil (0-20 cm) in the TPSF

No	Soil types (SNI/USDA)	Pyisical properties of soil/peat						
		Bulk density (Mg m)	Sand	Silt	Clay	Class	Water content	Material
1	Aluvial Eutric (Typic Tropofluvent)	0.79-1.01	23	34	43	Clay	12.3	Mixed peat
2	Aluvial Distric (Typic Dystropepts)	0.91-1.06	23	40	37	Silty clay	12.3	Mixed peat
3	Aluvial Gleic (Typic Tropaquent)	0.74-0.91	34	34	32	Loam	12.3	Mixed peat
4	Organosol Fibric (Typic Haplofibrist)	0.31-0.43	-	-	-	-	323.5	Peat
5	Organosol Hemic (Typic Haplohemist)	0.53-0.64	-	-	-	-	292.8	Peat
6	Organosol Sapric (Typic Haplosaprist)	0.61-0.72	-	-	-	-	182.3	Peat

Source: Soil analyzed (2013)

2. *Environmental degradation*

(a) Change of ground wáter level
Conversion of wetlands to oil palm plantations in the area TPSF decreased the ground water level. Field observations in general, it was found that the construction of drainage channels in the study area generally reaches a depth of 2-3 meters with a width of 1-3 meters. Construction of drainage channels in one side will accelerate the drying of land, making it easier for the company to commercialize its area for the garden the cultivation of oil palm or other crops. However, on the other hand a decrease in ground water level occurred due to decreased water holding capacity of peat.

Field observations indicated that groundwater levels vary depending on the thickness of the peat, the level of maturity, and the depth and duration of land used for crop business. But the most influential factor to the decline of the water level is the drainage depth and duration of the use of land for plantations. Increasingly in the drainage channel and the longer the use of land, the ground water level further away from the ground. The groundwater in the study area ranges between 0-2 m in areas with swamp forest vegetation. In the area of oil palm plantations with plant age <3 years, the ground water level ranged from 50 cm to 250 cm, while the peat in the area of oil palm plantations at the age of 3 to more than 10 years, the ground water level > 300 cm.

(b) Land subsidence
Field observations indicated land subsidance occured on the TPSF due to conversion to plantations. Land subsidence occured varies depending on the type and level of maturity and land use age of peat. In the immature peat (fibric), subsidence of land ranging between 20-80 cm from the initial ground, while on peat soil with moderate maturity level (hemic) and advanced (sapric) land subsidance can reach 100-150 cm from the initial soil conditions. This information is obtained based on the results of field measurements.

B. Land Rehabilitation
Some factors that cause degradation in the TPSF such as (1) Conversion of swamp forests for palm oil plantations by the company and for mixed farms by the public, (2) Construction of drainage channels by plantation companies causing excessive drainage, (3) deforestation conducted by the community for agricultural areas, and (4) forest/peat fires.

(1) Directives of land use and land conservation
Based on capability and suitability of land and land use requirements, the total area that can be redirected to serve as ecosystem conservation is an area of 19,257.53 hectares or 31.75 percent of the total area TPSF, while the cultivation of agricultural ecosystems which covers the development of plantations and agricultural dry land area of 41,399.76 hectares (68.25%). Directive of rehabilitation and conservation plans in the area of the TPSF are presented in Table 3.

Table 3. Directive of Land Use and Land Conservation in ecosystem of the TPSF

No	Directive of Land Use and Land Conservation	Area (ha)	Percentage (%)
1.	Conservation of Forest Swamp/Flora and Fauna	8,318.91	13.71
2.	Conservation of mangrove forest	748.96	1.23
3.	Conservation of coastal forest and coastal boundary	5,639.90	9.30
4.	Conservation area of Boundary River	4,549.76	7.50
5.	Agriculture/plantation	41,399.76	68.25
	Total	60,657.209	100.00

Sources: Observation and map analyses (2013)

(2) Water management (canal blocking)

Field observations indicated several canals drainage built too deep (> 2 meters). This will create excessive drying of the land. These conditions will give bad impact on the quality of the land and the environment. In the TPSF ecosystems, water management carried out over the entire area through the construction of drainage channels which are not in accordance with the rules of soil and water conservation. Land conservation needs to be done to maintain the ground water at a certain depth from the surface of the soil to support plant growth and preservation of the peatland. A layer of peat material should always be below the wáter surface because of peat easily shrink. Ground water level should be maintained at a depth of 60-80 cm from the ground. Setting the depth of the water is also beneficial to slow down the decay of peat, thereby reducing the rate of decline in the peat surface and provide aerobic zone for the development of oil palm roots.

Many researchers have also reported a solution to overcome the degradation of agricultural peatlands. Sabiham (2007) mentioned that the water management (macro and micro) greatly affect the characteristics of peat. Groundwater levels will affect the decomposition of peat (Land subsidence and irreversible drying). Querner *at al* (2012) mentioned that understanding impact of subsurface drains in combination with water level on subsidence and water supply needs in peatlands with agricultural land use are very important in restoration of peatlands. Ritzema *et al* (2014) reported restoration of degraded peatlands normally starts with restoring the water table to rewet the surface in order to control fire and to initiate reforestation by using canal blocking strategies. Koskinen *et al* (2011) reported restoration of drained peat land forest is an important tool in maintaining and improving biodiversity in the boreal region.

Conclusions

Conversion of the Tropical Peat Swamp Forest (TPSF) in Aceh Province Indonesia into oil palm plantations and mixed farms caused degradation of soil/peat and environmental degradation. Degradation of soil/peat was characterized by changes of water holding capacity and the chemical/physical properties of soil/peat. Environmental degradation was characterized by changes in groundwater levels and land subsidence. Efforts to restore land at the TPSF can be carried out in accordance with the direction of land use and conservation of land as well as water management.

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