Land Characteristics Evaluation Of Tripa Peat-Swamp For Palm Oil Plantation, Aceh Province, Indonesia

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Abstract.

Peat swamp forest has been continuing threatening in last decade. Tripa peat swamp forest plays important role in the system of watershed hydrology because of its ability to absorb water up to several times higher than its weight and its function as the enormous carbon reserves storage, either from above or below ground level. However, Tripa peat swamp has been used as palm oil plantation. It is important to evaluate the land characteristics to determine the level of suitability the area in order to put the area in term of environmental conservation. This paper presents a land suitability evaluation of Tripa Peat-Swamp Forest (TPSF), Aceh Province, Indonesia for palm oil plantation. The criteria of suitability used is referred to FAO and technical manual of Agricultural Land Resources for 16 land mapping units obtained. Selected parameters such as soil types, thickness and maturity of the peat, as well as the type of land use were utilized to obtain the land mapping units. Results show that more than half (above 52%) of TPSF area are not suitable for palm oil plantations. The main limiting factor is the land condition that iseasily inundated, the thickness of the peat layer>200 cm, and the maturity of the peat is at fibric-stage. Subclass categories were generating to predict the suitability level; moderate and marginal suitable. The areas which are suitable for palm oil plantations moderately suitable; called as S_2-rc which limiting factor is nutrient retention account for 8.97% of the area and marginally suitable; subclass S_3-nr,fh with limiting factor of soil fertility and flooding accounts for 43,03% of the total area investigated.

Key words:*Tripa peat swamp, land characteristics, palm oil.*

A. INTRODUCTION

Tropical peat swamp forest has been rapidly converted to agriculture, mainly for oil palm. Oil palm plantations had expanded tocover an area of 4.3 Mha on peat in Indonesia and Malaysia (Miettinenet al., 2016).Peat swamp forest ecosystem plays very important role in the system of watershed hydrology because of its ability to absorb water up to several times higher than its weight and its function as the enormous carbon reserves storage, either from above or below ground level (Wahyuntoet al., 2005). Limitations in understanding how peatlandsystems function has led to land degradation, which, for example hascaused uncontrollable burning of over a million hectares of Indonesianpeat during 1996, resulting from excessive land use change by theMega Rice Project (Page et al., 2002). One of the examples of the effects of peat ecosystem destruction is a flood in the lower reaches of the watershed (Galbraith et al., 2005). One of the main causes of swamp forest degradation is the conversion of swamp forest into agricultural land. Indonesia's peat swamp forest conversion to agricultural area especially for oil palm plantations has been continuing in several provinces, such as Kalimantan, Riau, South Sumatra, and Aceh. In Aceh province alone, one of the peat swamp forest ecosystem that has been converted into oil palm plantation and agriculture is found in Tripa peat swamp forest (TPSF) in Nagan Raya and Aceh Barat Daya Districts. The total area of TPSF is estimated at over 60,000 hectares (Sufardiet al., 2014; Basriet al., 2015).

Before being converted into the agriculture land or oil palm plantation, the TPSF is one of the swamp forest area which has various biodiversity and vast carbon content as most of the swamp contains abundant amount of carbon materials which is approximated to be over 100 million tons (Anhar, 2013). This swamp forest can also provide its role as the land to protect wildlife and at the same time serve as a buffer against global climate change. Nevertheless, The TPSF area has been degraded due to the land conversion from swamp forest land into oil palm plantations and mixed farms (Sufardi et al., 2013; Basri et al., 2015).

Having presence of land conversion, the TPSF area has been degraded and it eventually gives effects to the land use patterns that broadly affects the environmental changes (Sufardiet al., 2013; Basriet al., 2015), and patterns of socio-economic life on the neighboring communities (Egoh, 2007; Fajriet al., 2013).

Land-use change in peat swamp forest is commonly discussedfrom the perspective of carbon emissions, with a very limited literatureassociated with peatland properties, and even fewer studies associatedwith land characteristics leading to the suitable analysis of peat swamp forest for any land use, especially for oil palm. Land characteristics are important factors to determine the level of land suitability (Agricultural Land Resources Research Center 2014). This study is aimed to determines how peatcharacteristics as key driven factors affected for palm oil plantation. To achieve this, we tested the following hypothesis: Land-usechange of peat swamp forests for oil palm will have certain degree of suitability, and it will affect the peat swamp forest land use management and input needed for sustainable land use. Thus, this paper describes the suitability of the land in the TPSF area of Aceh Province to oil palm plantation.

B. MATERIALS AND METHODS

Procedures

The research was carried out in the area of Tripa peat swamp forest (TPSF) covering an of 60,657.29 hectares in Nagan Raya District, Aceh Province, Indonesia. Geographically the area located at 03º 44' – 03º 56' N and 96º 23' – 96º 46' E. To identify the difference of characteristics and land quality in the TPSF area, land mappingunits were determined by thematic maps overlay process. Symbolization of every land unit were notedto ease the suitable analysis for every land unit. Remote sensing data interpretation was carried out to determine current land use. Some parameters were collected and input into the of thematic maps generated such as: peat thickness, peat maturity, and land use. Analysis for some soil chemical properties, such as organic C content i.e. (C-N analyzer), total amount of P_2O_5 and K_2O from HCl 25% extraction, base saturation (BS), cation exchange capacity (CEC) by using NH_4OAC 1*N* pH7 method, and electrical conductivity (EC) with EC-meter were conducted to determine soil fertility status and later on to be used to determine land characteristics and suitability analysis. In addition, other characteristics were also examined such as the potential of pyrite, BV (bulk density) and the color of the soil. Peat thickness was measured by direct drilling in the field, whereas peat maturity was determined by McKenzie method. The presence of pyrite layer within the peat profiles were tested with peroxide (H_2O_2) 30% and measured on several range of depth of 0-20 cm, 40-60 cm and >60 cm (Mansur, 2001). The assessment of the soil fertility status is completely done using 5 indicators of soil chemical properties, i.e. CEC, BS, organic C, P_2O_5 and K_2O total, while land suitability for oil palm crops were evaluated and referred to the technical manual of Agricultural Land Resources Research Center 2014.

C. RESULT AND DISCUSSION

A. Land mapping unit and Land Use

We found that the TPSF consist of 16 land mapping unit with four existing of land uses, e.g swamp forests,mixed farms, palm oil plantations, and open land/shrub. The area also canbe divided into two orders of soil, i.e. Entisol (udifluvents, fluvaquents) and histosol (haplofibrist, haplohemists, haplosaprists (Soil survey staff , 2014) (see Tabel 1)

Table 1 shows that the area of TPSF can be distinguished into 16 units of land. The differences in the units of the land due to variations in soil type, thickness of peat, and maturity of peat.

Table 1. Mapping Units, Soil Classes, Peat thickness and Land uses of TPSF

No.	Mapping Unit	Soil class(USDA, 2014)	Peat thickness	Land useType
1	1AAd1	TypicUdifluvents	< 1-2 m	mixed farm
2	1AAe1	TypicUdifluvents	< 1-2 m	mixed farm
3	1AAg1	TypicFluvaquents	< 1-2 m	forest
4	2GHf1	TypicHaplofibrists	> 3 m	forest
5	2GHf2	TypicHaplofibrists	2 - 3 m	forest
6	2GHh1	TypicHaplohemists	> 3 m	forest
7	2GHh2	TypicHaplohemists	2 - 3 m	oil palm
8	2GHs1	TypicHaplosaprists	2 - 3 m	mixed farm
9	2GHs2	TypicHaplosaprists	> 3 m	oil palm
10	2GHs3	TypicHaplosaprists	2 - 3 m	mixed farm
11	2GHs4	TypicHaplosaprists	< 2 m	oil palm

12	2GHs5	TypicHaplosaprists	> 3 m	forest
13	2GHs6	TypicHaplosaprists	2 - 3 m	oil palm
14	1AAg2	TypicUdifluvents	< 1-2 m	mixed farm
15	1AAd2	TypicUdifluvents	< 1 m	oil palm
16	2GHs9	TypicHaplosaprist	2-3 m	oil palm
Total				

B. Soil Fertility Status

The results of the evaluation of soil fertility status in each land unit (SPL) in TPSF area are presented in Table 2

No.	LandUnit	Soil Class (USDA, 2014)	CEC	BS	C (%)	P_2O_5	K_2O
			(cmol kg^{-1})	(%)		(mg 100 g^{-1})	
1	1AAd1	TypicUdifluvents	VH	H	VH	M	H
2	1AAe1	TypicUdifluvents	VH	H	VH	M	H
3	1AAg1	TypicFluvaquents	VH	H	VH	M	H
4	2GHf1	TypicHaplofibrists	VH	VL	VH	VL	VL
5	2GHf2	TypicHaplofibrists	VH	VL	VH	VL	VL
6	2GHh1	TypicHaplohemists	VH	VL	VH	VL	VL
7	2GHh2	TypicHaplohemists	VH	VL	VH	VL	VL
8	2GHs1	TypicHaplosaprists	VH	VL	VH	VL	VL
9	2GHs2	TypicHaplosaprists	VH	VL	VH	VL	VL
10	2GHs3	TypicHaplosaprists	VH	VL	VH	VL	VL
11	2GHs4	TypicHaplosaprists	VH	VL	VH	VL	VL
12	2GHs5	TypicHaplosaprists	VH	VL	VH	VL	VL
13	2GHs6	TypicHaplosaprists	VH	VL	VH	VL	VL
14	1AAg2	TypicUdifluvents	VH	M	VH	H	H
15	1AAd2	TypicUdifluvents	VH	M	VH	M	H
16	2GHs9	TypicHaplosaprist	VH	VR	VH	VR	VL

Note:VH/H/M/L/VL = very high/high/medium/low/very low

Table 2 shows that the soil fertility based on TPSF area is divided into two levels: low and medium. Indicators which illustrate the low fertility of the soil are the alkalinity, and low content of P2O5 and K2O. CEC of soil and organic C content on the whole SPL are observed to be very high both on Histosol or Entisol. Based on these characteristics, then this TPSF land is heavily required to get moderate until high amelioration to be used as plantation land. Amelioration technique may involve applied fertilizer and liming.

This result indicates that the higher KTK and organic C content may not guarantee the high fertility level of land because it turns out that the alkalinity and CEC content of this land is very low. Ai Dariah et al., (2014) stated that factors contribute to swamp land characteristics which is usually found in topical area is high content of KTK and organic C yet following by low alkalinity. Therefore, swamp land requires some special and sustainable treatments (Maas, 1997). Maftuah (2012) suggested to give some ameliorate material and fertilizers

C. Current Land Suitability

The results suggest that land in TPSF area currently can be divided into three land suitability classes i.e. S2 (moderately suitable), S3 (marginally suitable), and N (not suitable). The actual land suitability class for oil palm in TPSF area and limiting factors are shown in Table 3.

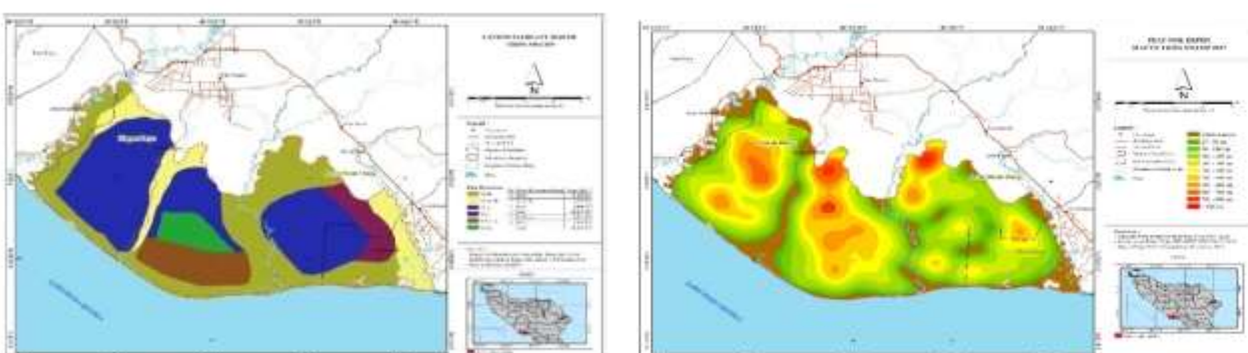
Tabel 3. Limiting factors of Land Unit and land area

No	Subclass	Land Unit	Limiting factor	Land Area Ha
1.	S2-fh	2, 3, 14	Flooding	19,484.0
2.	S2-nr, fh	1, 15	Soil fertility, flooding, nutrient retention	6,619.7
3.	S3-rc	11	Nutrient retention	2,844.4
4.	N-oa, rc	4, 5	Oxygen availability, nutrient retention, thickness and maturity of peat soil	4,842.3
5.	N-rc	6, 7, 8, 9, 10, 12, 13, 16	Nutrient retention, thickness of peat layer	26,866.9
Total				60,657.39

The results of land evaluation at any SPL show that there are approximately 29.000 acres of suitable land for planting palm oil with following estimation of each subclass area: 19,484.00 ha of S2-fh, 6,619.68 ha of S2-nr, and 2,844.37 ha of S3-rc. The Limiting factors of each subclass are nutrient retention (high soil acidity), low nutrient availability, poor surface drainage, and the danger of flood/inundation. The suitable land is presented on the SPL 1, 2, 3, 11, 14, and 15. The rest of it which were about 32,000 is not suitable for palm oil plantation with a subclass of 4,842.29 ha of N-oa, and 26,866.95 ha of N-rc. The main barriers on the land were peat thickness above 2 meters, acid soil chemical properties (pH >5.5), and the limited oxygen availability due to the frequent inundation and poor drainage

Tabel 4. The suitability of the actual land for oil palm on a variety of current land use patterns in areal the TPSF and limiting factors

No	Current land use	Symbol of subclass	Limiting factor	Land Areal ha
1.	Forest /swamp forest	N-rc N-oa, rc	flooding, peat thickness, and rates of peat maturity	11,455.5
2.	Mixed farm	N-rc S_3, rc S_2-nr, fh S_2-fh	Nutrient retention, flooding, nutrient availability	30,338.2
3.	Oil palm plantation	N-rc S_3, rc S_2-nr, fh S_2-fh	Peat thickness, nutrient availability, flooding	15,278.6
4.	Deforested land	S_3, rc	Peat thickness, nutrient retention	2,905.9
	Total			60,657.29



A B

Figure 1. Land Suitability Map (A) and the peat soil deep map (B) of TPSF

Table 4 shows that based on land suitability level for each pattern of land use; it gives result that all of the swamp area is not suitable for any crop plantation. On the other hand, in mixed farm area, the level of land suitability varied from S2 (moderately suitable) until N (not suitable). On open land, all land is stated to be fairly suitable (S3). The limiting factors of land suitability for suitable class are nutrients retention, a threat of flooding, and nutrient availability, while for unsuitable class, the limiting factors are peat thickness and peat maturity.

Based on those facts, it can be concluded that not all of the area which has been given some cultivation effort are suitable for planting according to land suitability result, yet land is already be opened for sought to appropriate the land according to the terms of the plantation, but had already opened to plantation activity at some points. The unsuitable land (N) for palm oil which is formed as swamp forest has 11,455.45 acre in total (20.53%), while the total area can be varied in mixed farm or palm oil land pattern. The barriers that might contribute to low suitability level of palm oil plantation are peat thickness above 2 m, fibric maturity and the presence of poor drainage or flooding.

In conclusions, we hav e determined the Tripa peat swamp forest area in Aceh province is one of peat soil area with its thickness varies from 0.5 m to > 8.5 m. The current state is no longer intact as swamp ecosystem because it has been converted into agricultural land and oil palm plantation, thus, its soil type and soil characteristics have been altered.More than half (52%) of TPSF area (32,000 ha) are not suitable for palm oil plantations. The main limiting factor is the land condition that is easily inundated, the thickness of the peat of >2 m, and the maturity of the peat-fibric.The areas which are suitable for palm oil plantations are divided into two subclasses i.e. moderately suitable (S2-fh; S2-nr,fh) 43.03% and marginally suitable (S3-rc) 8.97%. The limiting factors on the use of land for palm oil cultivation on TPSF areas are nutrient retention, soil fertility, and flooding

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REFERENCES

Ai Dariah, E. Maftuah, and Maswar. 2014. Karakteristik lahan gambut. In N.L. Nurida and A. Wihardjaka (Eds.) Panduan Pengelolaan Berkelanjutan Lahan Gambut Terdegradasi. Badan Penelitian dan Pengembangan Pertanian, Bogor.

Anhar, A. 2013. Assessment of The Below Ground Carbon. In Main Report of Scientific Studies for The Rehabilitation and Management of The Tripa Peat-Swamp Forest. Syiah Kuala University, Banda Aceh, Indonesia. 387-414.

Basri, H., Sufardi, Sugianto, S. A. Ali, and Khairullah. 2015. How to restore the tropical peat swamp forest in Aceh Province, Indonesia. Proceeding of The 5th Annual International Conference (AIC) Unsyiah, 9-11 September 2015. Banda Aceh 1-6 p.

Research Headquarter for Agricultural Land Resources. 2014. Technical Evaluation of Land Resources (Petunjuk Teknik Evaluasi Sumberdaya Lahan). Badan Penelitian dan Pengembangan Pertanian. Bogor, Indonesia.

Egoh, B. 2007. Integrating ecosystem services into conservation assesment: A Review. J. Ecological Economics. 63 : 714-721.

Fajri, and Agussabti. 2013. Sosio-economic and concerning life. In. Scientific Studies for The Rehabilitation and Management of The Tripa Peat-Swamp Forest. Syiah Kuala University, Banda Aceh, Indonesia. 187-236.

Galbraith H, P Amerasinghe and HA Lee. 2005. The Effects of agricultural irrigation on wetland ecosystems in Developing Countries: A literature review. CA Discussion Paper 1 Colombo, Sri Lanka: Comprehensive Assessment Secretariat.

Maas, A. 1997. Pengelolaan lahan gambut yang berkelanjutan dan berwawasan lingkungan. Jurnal Alami 2 (1) : 12-16.

Maftuah, E. 2012. Ameliorasi lahan gambut terdegradasi dan pengaruhnya terhadap produksi jagung manis. Disertasi Program Pascasarjana UGM, Yogyakarta.

Mansur. 2001. Teknik Pengamatan Pirit pada Lahan Rawa Bergambut.

Miettinen, J., Shi, C., Liew, S.C., 2016. Land cover distribution in the peatlands ofPeninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990. Global; Ecology Conservation. 6, 67–78

Page, S, F. Siegert, J.O. Rieley, H.V. Boehm, A. Jaya, and S. Limin. 2002. The amount of carbon released from peat and forest fires in Indonesia during 1997. Nature (420):61-65.

P3MT. 1983. Panduan Teknis Penilaian Kesuburan Tanah. Pedoman Pelaksanaan Pemetaan Lahan Menunjang Transmigrasi. Deptan Republik Indonesia. 34 p.

Soil Survey Staff. 2014. Keys to Soil Taxonomy. Twelfth Eddition. Natural Resources

Conservation Service, United State Department of Agricultural, Washington DC, 362 p.
Sufardi, S. A. Ali, Khairullah, Sugianto. 2013. Technical Design for Land Rehabilitation. In. Scientific Studies for The Rehabilitation and Management of The Tripa Peat-Swamp Forest. Syiah Kuala University, Banda Aceh, Indonesia. 237-294.
Sufardi, Hairul Basri, S. A. Ali, Khairullah, Sugianto. 2014. Profil Biofisik Ekosistem Hutan Rawa Gambut Tripa Provinsi Aceh, Indonesia. Prosiding Seminar Nasional BKS PTN Wilayah Barat, Palangka Raya.
Wahyunto, Ritung S, Suparto, Subagjo H. 2005. Peat land distribution and carbon content in Sumatera and Kalimantan. Wetland International-Indonesia Program and Wildlife Habitat Canada (WHC). Bogor-Indonesia