ENVIRONMENTAL RISKS OF FARMING PEAT LAND

Fahmuddin Agus
Indonesian Soil Research Institute, Jln. Juanda 98, Bogor 16123, Indonesia;
f.agus@cgiar.org; Fax: 62-251-8321608

Abstract
Aceh is one of the provinces in Indonesia undergoing a rapid development that entails the conversion of forest lands, including the marginally suitable peat lands, to agriculture. The peat land of Aceh has an area of about 0.27 million ha and stores as much as 561 million ton (Mt) of C or about 2000 t C ha^{-1} underground. Carbon stocks are preserved under the natural peat land forest. Once the peat forest is converted and drained, the carbon rich peat land contributes to green house gas (especially CO_2) emissions through three processes: (i) burning of the tree biomass during land clearing, (ii) burning of peat layer during peat forest burning that often coincides with land clearing, and (iii) decomposition of peat because of drainage. Burning during the land clearing process can emit as much as 367 t CO_2 ha^{-1} from the tree biomass and 275 t CO_2 ha^{-1} from the burning of 15 cm of the peat layer. During crop cultivation, peat decomposition continues and its rate depends on the water table depth (as regulated by drainage depth) and on the farming practices. Plantation with a drainage depth of 60 cm may generate as much as 55 t CO_2 ha^{-1} yr^{-1}. About 90 cm peat subsides through burning during land clearing and decomposition during the 25 year oil palm cultivation. In addition, subsidence at the rate of 50 to 115 cm per 25 year also occurs concomitantly during crop production due to peat compaction. In total, the subsidence reaches 135 to 200 cm within 25 years - one cycle of oil palm production - leaving the surrounding areas very prone to flooding and droughts. This sustainability and environmental aspects of farming on peat land should be taken into account before making an economically based investment.

Introduction
The rapid agricultural development causes the utilization of marginally suitable land for agriculture, including the environmentally very fragile peat lands. In Riau, for example, about 57% (1,831,193 ha) of peat land forest has been lost during the last 25 year period (from 1982 to 2007) (WWF, 2008). Similar or perhaps even a more rapid conversion of peat land to agriculture may happen in Aceh on the 0.27 million ha peat land due to the conducive security situation after the Independence Aceh Movement (GAM) ended and higher government priority on the economic development.
Under the natural condition, peat land is a carbon sink by forming gradually the peat dome. From a peat core in Central Kalimantan, it was found that the time range of peat formation was between 24,000 to 100 years before present for the peat layers between 9 to 1 m, respectively. The peat formation ranges from a fraction to 2-3 mm thick annually and in some years the formation may be negative because of prolong droughts (Rieley et al., 2008). When peat forest is cleared and drained, the oxidized layer decompose and emit a significant amount of CO2. The method of land clearing and the successive land use and management systems determine the rate of CO2 emissions. Land use such as paddy system which requires minimal drainage, likely emit minimal below ground carbon. Oil palm plantation with average drainage depth of 60 cm could emit as high as 55 t CO2 per ha annually (Hooijer et al., 2006) and this translates to the peat loss of 30 mm $year^{-1}$ (orders of magnitute faster than the peat formation).

Besides contributing to atmospheric CO_2, peat CO_2 emissions also cause subsidence because of the peat mass loss. Simultaneously, subsidence also occur because of peat compaction resulted by peat draining. The two processes of subsidence (through emissions and compaction) lead to the area susceptibility to floods and droughts because peat can retain as high as 90% of water by volume.

The impacts of peat forest clearing are of local and, at the same time, global significance, because:

- Global warming threatens the survival and reduce productivity of existing fauna and flora
- Extreme weather conditions resulted from global warming (high intensity rains and long droughts) are problematic globally and locally
- Melting of glacier, causing disappearance of small islands and flooding in the low lying coastal areas; for which Indonesia is very vulnerable.
- Loss of biodiversity

This paper discusses the environmental consequences in terms of (i) processes and sources of CO_2 emissions as peat land forest is converted to plantation and (ii) subsidence and sustainability as peat land is converted. Implications for policy are discussed in the concluding section.

Peat land distribution and carbon stock

Peat land covers an estimated 240 million hectares worldwide. Some 200 million hectares are situated in the boreal and temperate regions of North America, Europe and Asia. The rests are in the tropics and subtropics with the most prominent formations occurring in the coastal lowlands of Southeast Asia, with about 20 million hectares located in Indonesian archipelago (Driessen and Dudal, 1989).

The area of peat land in Sumatra is 7.2 million ha and its below ground (excluding plant roots) carbon stock is 22,283 Mt (mega ton or million ton) or about 3,095 t C ha^{-1} on average. For comparison, peat land area in Kalimantan is about 5.77 million ha and contains about 11,274 Mt below ground carbon or an average of about 1,954 t ha^{-1} (Wahyunto et al., 2003 and 2004; Table 1). The coastal peat swamp on the west coast of Aceh covers a total area of circa 270,000 ha; meaning that every ha contains about 2000 t C (Table 1).

Carbon content of peat land per unit area that ranges from 450 to 3000 t/ha (Table 1) is way above carbon content in the first 30 cm of mineral soils ranging from 30 in the degraded to 210 t/ha in Andisols. In addition, the above ground biomass of peat forests contains about 200 t C/ha, although in the non peat forest it ranges from 250 to 300 t/ha.

Table 1: Area and below ground carbon stock of peat land in provinces in Sumatra, Kalimantan and Papua (Wahyunto et al., 2003; 2004; 2007).

Island/province	Area (mil. ha)	C stock (Mt)	C Stock (t/ha)
SUMATRA	7.200	22,283	3,095
Aceh	0.274	561	2,047
North Sumatra	0.325	561	1,726
West Sumatra	0.210	508	2,419
Bengkulu	0.063	92	1,460
Riau	4.044	16,851	4,167
Jambi	0.717	1,851	2,582
Bangka Belitung	0.069	72	1,039
South Sumatra	1.420	1,729	1,218
Lampung	0.088	60	682
KALIMANTAN	5.769	11,275	1,954
PAPUA&PAPUA BARAT	8.0	3,623	454

CO_2 emissions from peat land

Peat emits CH_4 and CO_2 gases, but the proportion of CO_2-e CH_4, is much lower or even negligible compared to the amount of CO_2 emitted (Jauhiainen, 2004). Therefore, only CO2 emissions are considered in this discussion.

CO_2 emissions from the peat land when forest is converted to agricultural land, can be described by Equation [1].

$$E = E_a + E_{bd} + E_{bc} + E_{bo} - S_a \quad [1]$$

The definition and assumptions associated with each term can be explained as follows:

E_a is the emission from the above ground biomass burning. E_a is estimated based on the above ground C stock (t/ha) * 0.5 * 3.67. The factor of 0.5 is our assumption for the 50% burned plant biomass while the remaining 50% is assumed to be converted to timber products. This assumption applies for primary and secondary forest conversion. The 3.67 is the conversion factor from C to CO_2 based on the atomic weight comparison. For peat forest we assume that the carbon stock is 200 t ha^{-1} (Rahayu *et al.*, 2005).

E_{bd} is the emissions from below ground peat burning during deforestation. E_{bd} = volume of peat burned (m^3) * C density (t/m^3)*3.67. The volume of peat burned can be estimated by the average depth of burned peat multiplied by the burned area. In this calculation we assume that the average depth of burned peat during deforestation is as deep as 15 cm as proposed by Hatano (2004) for normal year, although Page *et al.* (2002) suggested that the burning depth could be as deep as 50 cm during El Niño years. We justified the 15 cm burning because, during the dry season of 2006 (normal year) in East Kalimantan and Painan, West Sumatra we observed very patchy shallow (<<10 cm) burning. Water table levels ranged between 40 to 70 cm, which was exceeding the fire risk threshold value of 30 cm (Wösten et al., 2006). Carbon content is assumed as high as 50 kg m^{-3}.

E_{bc} is emission from below ground burning during crop cultivation which is equal to the volume of peat burned (m^3) * C density (t/m^3)*3.67. The burning is often conducted intentionally in traditional farming in order to increase the peat soil pH and soil fertility. A similar practice, known locally as the 'sonor' system – a kind of rice shifting cultivation on peat land, is found in South Sumatra (Agus *et al.*, 2007). No less than 2 cm of peat is burned every year through this practice.

E_{bo} is the emission from below ground peat decomposition (t CO_2/ha/yr). Drainage depth or the depth of water table is the main determining factor of the decomposition rate. Although uncertain of the accuracy, based on empirical relationship from green house gas emission research, Hooijer et al. (2006) suggested that the emissions rate increases 0.91 t

CO_2 ha^{-1} with one cm drainage depth increase. Our assumed values for the average drainage depths for vegetable/maize, paddy rice system, rubber and oil palm are 30, 10, 20 and 60 cm, respectively.

S_a is sequestration in the above ground plant biomass and this amount equals the time average above ground C stock in the alternative land use (t/ha) * 3.67. Oil palm and rubber sequestrate as much as 60 and 56 t C ha-1 (IPCC, 2003; Rogi 2002)

Based on these assumptions Figure 1 shows annual average CO_2 emissions when peat forest is converted to various agricultural land uses. It must be understood that the S_a and E_{bo} components of the emissions occurred only during the land clearing process while the rest occurs during the cultivation stage.

Vegetable production on peat soil emits the highest amount of CO_2 and the highest contributor to the emissions is peat burning for soil fertility improvement. The area cultivated by each household for the traditional farming is only a couple of ha and scattered but this practice depletes the peat layer and causes subsidence and emissions. Peat decomposition from vegetable cultivation areas is also relatively high.

Oil palm is believed to emit the highest amount of CO_2 among estate crops due to the deep drainage. Our assumption of 60 cm average drainage depth may be considered as the lowest limit since in some places the primary drainage canal could be a couple of meter deep while the field tertiary canal is about 60 cm. However, systematic long terms data for the relationship of drainage depth and emission rate are lacking to verify the drainage depth and emission rate relationship as suggested by Hooijer et al. (2006).

Rice paddy and rubber plantation systems require rather shallow drainage and accordingly lead to the lowest emissions. However rice yield on peat soil is usually low and unsustainable due to various nutrient deficiency and toxicity problems.

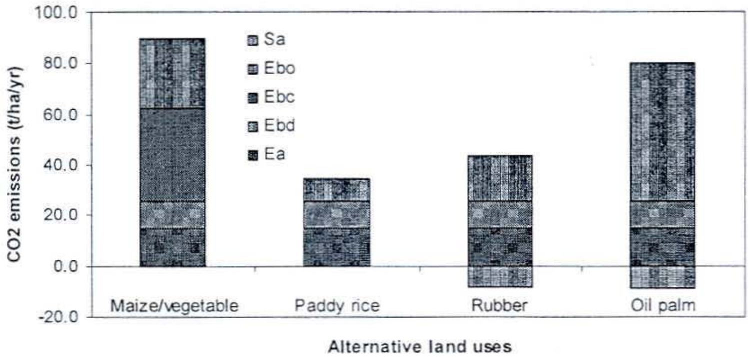

Fig. 1: Annual average CO_2 emissions estimates from peat forest conversion to various agricultural land uses. Time average was based on 25 year crop cycle(s).

Peat subsidence

Peat subsidence occurs through two processes: compaction or shrinkage and the mass loss due to oxidation (peat decomposition and burning). Peat compaction occurs very rapidly immediately after the drainage canal is constructed and, after a few years of drainage, it stabilizes to two to 4.6 cm annually, depending on the drainage depth (Wösten, 1997). Peat oxidation depends on the rate of peat burning and peat decomposition. Figure 2 presents the result of sample calculation of subsidence due to oxidation. The sum of subsidence from compaction and oxidation could be around 2 m in 25 years under oil palm plantation and shallower for other land uses with shallower drainage. A two meter subsidence translates to about 1.8 m loss of the peat water retention capacity, causing the surrounding areas susceptible to floods in the rainy season and to droughts in the dry season.

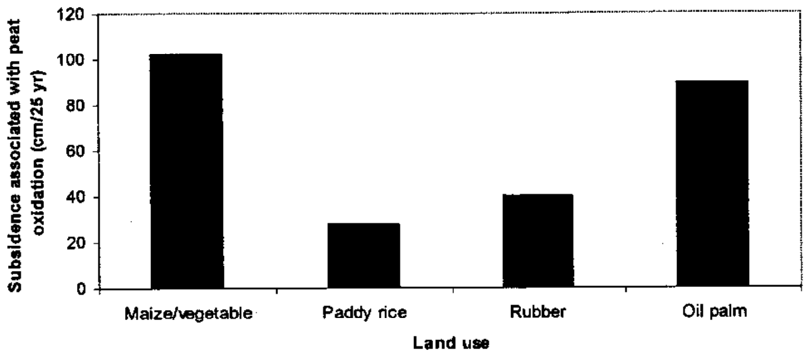

Fig. 2: Estimated peat subsidence in 25 year period due to peat decomposition and peat burning. Additional subsidence due to compaction could be as high as 50 to 100 cm in 25 years.

Implication

Land suitability, environmental and economic aspects should be taken into account when planning the development of peat forest into agriculture. The environmental aspect is perhaps the weakest consideration and tends to be overlooked when the economic incentives are high.

In theory, peat land deeper than 2 m is unsuitable for plantation crops, but when there is mineral layer enrichment (that may be brought by floods) the 2-4 m depth is only marginally suitable (Djainudin et al., 2003). The deep peat is environmentally very important for water conservation. Its capacity to retain 90% of water from its total volume is vital for buffering the surrounding areas against floods and droughts. Floods and droughts also threaten the sustainability of agriculture in the converted areas. Moreover, the Presidential Decree (KEPPRES) No. 32/1990, stipulates that peat deeper than 3 meters must be conserved for environmental protection. Finally, the growing global issues (which is at the same time very relevant locally) of peat CO_2 emissions as peat forest is converted should leave very weak justifications for peat forest conversion.

In practice, however, little attention has been given to the suitability, environmental and regulatory barriers as demonstrated in the One Million ha Rice Mega Project and in many plantation concessions. The One Million ha Mega Project, for example failed to contribute to the food security and created serious hydrological, biodiversity and green house gas problems because of lack of planning. Many plantations have successfully contributed to the local and national economies, albeit with the sacrifice of the peat environmental functions. Economic and livelihood objectives usually prevail over other considerations.

Learning from past experience, evaluation of the peat land suitability prior to their development is the key for the economic success. In areas where economic and livelihood pressures are very strong, deforestation may be unavoidable. The recent escalation in economic incentives for palm oil production and the complicated bureaucracy of the carbon trading mechanisms have increased the abatement and transaction costs of emission reduction. Our unpublished abatement cost estimates for avoiding peat land and non peat land forest conversions to oil palm plantation, were respectively over \$6 and over \$20 per ton of emitted CO_2; the values unlikely reachable through the Reducing Emissions from Deforestation and Degradation (REDD) mechanism. Nevertheless, solving the environmental problems amid the shadow of the economic and livelihood prospects must continually be negotiated between the local people and the governments as well as the international community.

References

Agus F, Suyanto, Wahyunto, and M. van Noordwijk. 2007. Reducing emission from peat land deforestation and degradation: Carbon emission and opportunity costs. Paper presented in "International Symposium and Workshop on Tropical Peat land "Carbon – Climate - Human Interaction - Carbon pools, fire, mitigation, restoration, and Wise Use", Yogyakarta, Indonesia, 27-29 August 2007.

Chokkalingam, U., S. Suyanto, R.P. Permana, I. Kurniawan, J. Mannes, A. Darmawan, N. Khususyiah, and R.H. Susanto. 2007. Community fire use, resource change, and livelihood impacts: The downward spiral in the wetlands of southern Sumatra. *Mitigation and Adaptation Strategies for Global Change* 12(1):75-100.

Djaenudin, D., H. Marwan, H. Subagjo, and A. Hidayat. 2003. Petunjuk Teknis Evaluasi Lahan untuk Komoditas Pertanian (Manual for Land Suitability Evaluation of Agricultural Crops). Balai Penelitian Tanah, Puslitbang Tanah dan Agroklimat Bogor (*In Indonesian*).

Driessen, P.M. and R. Dudal. 1989. Lecture notes on geography, formation, properties and use of the major soils of the world. p. 93-103. Agricultural University, Wageningen and Katholiek Universiteit Leuven. Wageningen and Leuven.

Hatano, R., M. Tomoaki, D. Untung, S.H. Limin, and A. Syaiful. 2004. Impact of agriculture and wild fire on CO2, CH4 and N2O emissions from tropical peat soil in Central Kalimantan, Indonesia: Necessity of Establishment of Inventory on Carbon Cycling in Tropical Peat land Ecosystems for Sustainable Agroproduction and Environmental Conservation. Report No. 13574012, Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, pp. 11-14

Hooijer, A., M. Silvius, H. Wösten, and S.E. Page. 2006. Peat-CO_2, Assessment of CO_2 Emissions from drained peat lands in SE Asia. Delft Hydraulics report Q3943.

IPCC (Intergovernmental Panel on Climate Change). 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Volume IV, IPCC.

IPCC. 2006. IPCC Guidelines for National Greenhouse Gas Inventories. H.S. Eggleston, L Buendia, K Miwa, T. Ngara and K Tanabe (eds.). The National Greenhouse Gas Inventories Programme, IGES Japan.

Jauhiainen, J., H. Vasander, A. Jaya, I. Takashi, J. Heikkinen and P. Martikinen. 2004. Carbon balance in managed tropical peat in Central Kalimantan, Indonesia. In *Wise Use of Peat lands - Proceedings of the 12th International Peat Congress, 06.-11.06.2004, Tampere*, volume 1, Päivänen, J. (ed.), International Peat Society, Jyväskylä, Finlandia. pp. 653-659.

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

Rahayu, S., B. Lusiana, and M. van Noordwijk. 2005. Above ground carbon stock assessment for various land use systems in Nunukan, East Kalimantan. pp. 21-34. In: Lusiana, B., van Noordwijk, M., and Rahayu, S. (eds.) *Carbon Stock Monitoring in Nunukan, East Kalimantan: A Spatial and Modelling Approach.* World Agroforestry Centre, SE Asia, Bogor, Indonesia.

Rieley, J.O., R.A.J. Wüst, J. Jauhiainen, S.E. Page, H. Wösten, A. Hooijer, F. Siegert, S.H. Limin, H. Vasander and M. Stahlhut. 2008. Tropical peat lands: carbon stores, carbon gas Emissions and contribution to climate change Processes. pp. 148-182 *In* M. Strack (Ed.) Peat lands and Climate Change. International Peat Society, Vapaudenkatu 12, 40100 Jyväskylä, Finland

Tomich, T.P. 1999. Agricultural Intensification, Deforestation, and the Environment: Assessing Trade offs in Sumatra, Indonesia. Proceedings of the International Symposium "Land Use Change and Forest Management for Mitigation of Disaster and Impact of Climate Change", Bogor, 19-20 October, 1999. pp. 1-27.

Wahyunto, Subagjo, et al. 2007. Map of Peat land Distribution Area and Carbon Content in Papua. Wetland International-Indonesia Program and Wildlife Habitat Canada (WHC).

Wahyunto, S. Ritung and H. Subagjo. 2003. Map of Peat land Distribution Area and Carbon Content in Sumatra. Wetland International-Indonesia Program and Wildlife Habitat Canada (WHC).

Wahyunto, S. Ritung, Suparto and H. Subagjo. 2004. Map of Peat land Distribution Area and Carbon Content in Kalimantan. Wetland International-Indonesia Program and Wildlife Habitat Canada (WHC).

Wösten, J.H.M., A.B. Ismail, and A.L.M van Wijk. 1997. Peat subsidence and its practical implications: a case study in Malaysia, Geoderma, 78, 25-36.

Wösten, J.H.M., van J. der Berg, P. van Eijk, G.J.M. Gevers, W.B.J.T. Giesen, A. Hooijer, A. Idris, P.H. Leenman, D.S. Rais, C. Siderius, M.J. Silvius, N. Suryadiputra, I.T. Wibisono. 2006. Interrelationships between hydrology and ecology in fire degraded tropical peat swamp forests, International Journal of Water Resources Development, 22, 157-174.

WWF (World Wildlife Foundation) Indonesia. 2008. Deforestation, forest degradation, Biodiversity Loss and CO2 Emissions in Riau, Sumatra, Indonesia. WWF Indonesia Technical Report, Jakarta, Indonesia. 75 p.