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Carbon Stock and Tree Diversity in Tripa Peat Swamp Forest

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Abstract

Peat swamp forest currently gets great attention owing to its high storage capacity of belowground carbon. Tripa peat swamp forest is a part of *Kawasan Ekosistem Leuser (KEL)* in Aceh province has a high conservation value as a habitat of the endangered species of Sumatran orang-utan (*Pongo abelii*). Aboveground carbon stock was measured in an agro forest area and three forest types, viz. undisturbed, disturbed and secondary forest using standard protocol. Average density of aboveground carbon stock in the 4 different land use types ranged from 28.5 t/ha to 193 t/ha, in agroforest area and undisturbed peat forest respectively. Besides its capacity to store carbon, Tripa peat swamp forest had a high diversity of tree species with Shannon Wiener index of 3.61. Many species of food source for orang-utan occurs in the forest with high Important Value Index, such as *Eugenia jambos, Eugenia curtisii, Litsea cubeba* and *Laurus nobilis.* Forest clearing and conversion to oil palm plantation were two threats of the lost of Sumatran orang-utan habitat in Tripa.

Key words: high conservation value forest (HCVF), habitat, Sumatran orang-utan

Introduction

Conservation of biodiversity and mitigation of global warming are two major environmental challenges today (Gaveau *et al*., 2009). The conservation of critically endangered species such as the Sumatran orang-utan (*Pongo abelii*) is a global priority. The Sumatran orang-utan occurs in Aceh and North Sumatra in relatively high densities in peat swamp forest (in the few places where that is left) and in lowland forest. The swamp forests have an abundance of fruits that support orang-utan in periods when fruits are scarce in other areas and the higher densities in this habitat are linked to different social behaviour.

Tripa is one of remnant peat swamp forest in west-coast Aceh, which is known as habitat of Sumatran orang-utan. The two greatest threats to orang-utan survival are habitat loss and illegal trade in the animals. The Tripa peat swamp forest is currently under pressure owing to extensive conversion to oil palm plantations. Conserving habitat through payment for reduced emissions from deforestation and degradation is now becoming attractive but needs quantification. Measuring carbon stock at plot and landscape level is one method that can be used to estimate carbon emissions (Lusiana *et al.,* 2002). Alongside the plot assessment of carbon stocks, relevant data on tree diversity can be collected to assess which species are likely to complete their life cycle in various habitat types.

This study aims to calculate aboveground carbon stocks and tree diversity as orang-utan's food in Tripa, Aceh.

Method

The study was conducted in Tripa peat swamp forest, which is laid on two districts, e.g. Nagan Raya and Aceh Barat Daya, Aceh province. According to the Intergovernmental Panel on Climate Change (IPCC), we assessed three carbon pools, e.g. aboveground biomass (tree and understorey), dead wood, and surface litter (necromass). The sampling method used in this survey refers to the Alternative Slash and Burn (ASB) protocol (Hairiah *et al.,* 2001).

Forest cover in Tripa had been classified based on visual observation and information from local informants. It is classified as undisturbed peat forest or virgin peat forest; disturbed peat forest, when timber logging had occurred; and as secondary forest if the forest was a result of clearing or fire regrowth. The condition of disturbed peat forest in Tripa is shown in Figure 2.

Three nested sub-plots were established in each sample plot depending on vegetation: 40 m x 5 m sub-plot for counting trees and dead wood between 5 to 30 cm diameter; 100 m x 20 m plots for measuring trees and dead wood of more than 30 cm diameter; quadrant of 2 x 0.5 m x 0.5 m set up inside the sub-plot used to count under storey, litter and soil.

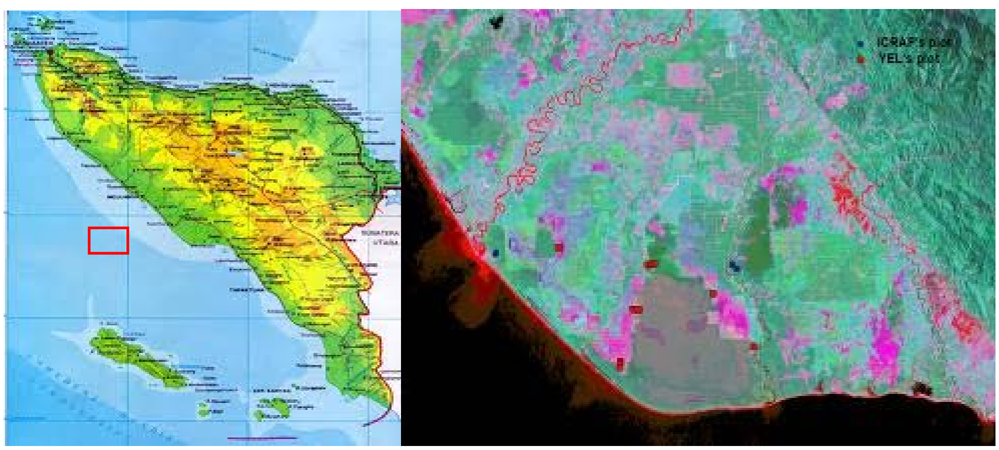

Fig. 1. Aceh map and Tripa position (insert, left); plot samples of carbon-stock measurement in Tripa study area (right).

Results and Discussion

Aboveground carbon stock. Land use in Tripa was dominated by oil palm, even though there were still patches of degraded and secondary forest, as well as undisturbed peat swamp forest in two oil palm concessions. Carbon-stock measurement had been done in secondary forest, primary forest low and high density in 2007 (data of Yayasan Ekosistem Lestari, YEL) and in 2010 (this study).

During the assessment in April 2010, a mature male orang-utan was observed in the remnant forest of Kuala Tripa. Otherwise, potential threats to orang-utan habitat appeared in Kuala Seumayam, because the remnant degraded forest in this area was being opened by the local community.

Fig. 1. Cover condition of disturbed forest in Kuala Tripa: (A) and Kuala Seumayam (B) (Photo: Rahayu Oktaviani)

Table 1. Number of sample plots for carbon-stock assessment in Tripa

No	Land uses	Number of plot
1	Undisturbed peat forest ICRAF 2010	3
2	Undisturbed peat forest YEL/PanEco/ICRAF 2007	6
3	Disturbed peat forest YEL/PanEco/ICRAF 2007	6
4	Disturbed peat forest of ICRAF 2010	6
5	Agroforest of YEL/PanEco/ICRAF 2007	2

Three types of forests, that is, undisturbed peat forest, disturbed peat forest and agroforest, which consist of regenerated vegetation and burned forest at 1996, were used in this study to differentiate carbon stock density. Average carbon stock density in each type of forest was 193 ton ha^{-1} from undisturbed peat forest of YEL/PanEco/ICRAF 2007 and ICRAF 2010 survey, 84 ton ha^{-1} from disturbed peat forest YEL/PanEco/ICRAF 2007 and ICRAF 2010 survey, 112 ton ha^{-1} from disturbed forest of ICRAF 2010 survey and 28.5 ton ha^{-1} from agroforest in peat of YEL/PanEco/ICRAF 2007 survey, respectively (Figure 3).

Data collected in 2007 (Van Belle and Hennin, 2008) were compared with the 2010 data set. These authors classified Plot-1, Plot-2, Plot-2, Plot-4, Plot-5, Plot-6, Plot-7, Plot-13 and Plot-14 as primary forest. In the data set, high-density primary forest (Plot-5, Plot-6, Plot-7, Plot-13) was differentiated from low-density forest (Plot-1, Plot-2, Plot-3, Plot-4, Plot-14). Plot-8, Plot-9 and Plot-10 were classified as burnt forest, while Plot-11 and Plot-12 as regenerated forest. Plot-7 had the highest carbon density: 388 t ha^{-1}. Other plots in their survey were in the same range as the 2010 data collected for similar forest types.

Tree biomass was the largest component of aboveground carbon stock (Table 2), with understorey contributing about 10% in disturbed peat forest (or degraded forest) where pandanus, small palm and other woody shrubs grow, in the Kuala Tripa area. Compared to other forest types, necromass carbon stock in the secondary forest was relatively high owing to standing dead and fallen trees after the fire.

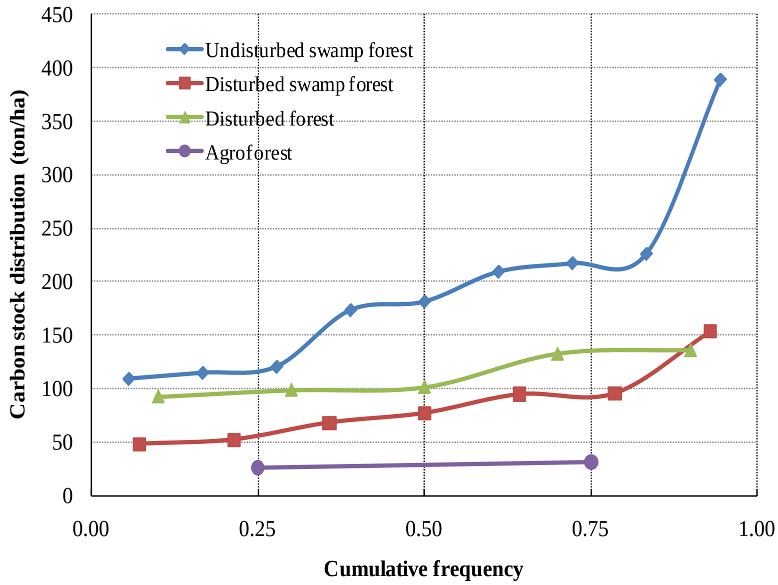

Fig. 3. Cumulative frequency of aboveground carbon stock based on land cover classification in Tripa area

Data collected in 2007 (Van Belle and Hennin, 2008) were compared with the 2010 data set. These authors classified Plot-1, Plot-2, Plot-2, Plot-4, Plot-5, Plot-6, Plot-7, Plot-13 and Plot-14 as primary forest. In the data set, high-density primary forest (Plot-5, Plot-6, Plot-7, Plot-13) was differentiated from low-density forest (Plot-1, Plot-2, Plot-3, Plot-4, Plot-14). Plot-8, Plot-9 and Plot-10 were classified as burnt forest, while Plot-11 and Plot-12 as regenerated forest. Plot-7 had the highest carbon density: 388 t ha^{-1}. Other plots in their survey were in the same range as the 2010 data collected in undisturbed forest.

Carbon tree contributed high component of carbon stock (Table 2). In undisturbed peat forest, tree contributed high percentage of carbon stock that is 95%, while in disturbed peat forest and secondary peat forest decreased to 87% and 79%, respectively. Understorey contributed about 10% of carbon in disturbed peat forest (or degraded forest) where pandanus, small palm and other woody shrub grow in Kuala Tripa area. Compared to other forest type, carbon of necromass in secondary forest is higher due to some standing dead and felt down tree after burning.

Agus and Wahdini (2008) reported belowground carbon stock in Tripa. Peat depth in the Tripa area (see plot samples in Figure 1) ranged from 130–505 cm, categorized as moderate (100–200 cm), deep (200–400 cm) to very deep peat (>400 cm). Average carbon stock in peat at moderate depth was 382 t ha^{-1}, deep was 1368 t ha^{-1} and very deep was 1621 t ha^{-1}. Peat density in Tripa was low and in the range 0.01–0.03 g cm^{-1} and carbon content was 12–63%, resulting in an average of 4.19 tC ha^{-1} cm^{-1} and a carbon stock that ranged from 382 t ha^{-1} for a 130 cm depth profile to 2240 t ha^{-1} for a location with a depth of 390 cm. According to the Presidential decree no.32 in 1990, peat depth more than 3 m must be conserved and is not allowed to convert to agriculture land. However, some peat domes in Tripa have been converted and only remain an area of 6000 ha of forest which is located inside an oil palm concession.

Table 2. Carbon stock of tree, understorey, litter and necromass in each plot sample

Plot code	Forest type	Tree (tC ha^{-1})	Understorey (tC ha^{-1})	Litter (tC ha^{-1})	Necromass (tC ha^{-1})	Total (tC ha^{-1})
Plot-1*	Disturbed swamp forest	87.77	7.75	0	0	95.51
Plot-2*	Disturbed swamp forest	91.03	3.68	0	0	94.71
Plot-3*	Undisturbed swamp forest	115.15	5.15	0	0	120.3
Plot-4*	Undisturbed swamp forest	104.06	10.56	0	0	114.62
Plot-5*	Disturbed swamp forest	139.91	13.52	0	0	153.43
Plot-6*	Undisturbed swamp forest	204.76	5.61	6.72	0	217.09
Plot-7*	Undisturbed swamp forest	378.54	5.7	4.18	0	388.42
Plot-8*	Disturbed swamp forest	23.58	4.42	1.1	22.91	52.02
Plot-9*	Disturbed swamp forest	56.08	0.55	5.52	5.81	67.96
Plot-10*	Disturbed swamp forest	65.41	2.58	1.84	7.14	76.96
Plot-11*	Agroforest	25.65	0	0	0	25.65
Plot-12*	Agroforest	30.93	0	0	0.36	31.29
Plot-13*	Undisturbed swamp forest	214.19	7.36	4.23	0	225.78
Plot-14*	Undisturbed swamp forest	173.21	0	0	0	173.21
KT1	Disturbed swamp forest	45.07	2.76	0	0.06	47.9
KT2	Undisturbed swamp forest	105.95	1.5	1.64	0	109.08
KT3	Undisturbed swamp forest	68.23	137.37	2.45	1.07	209.13
KT4	Disturbed forest	129.42	0.62	5.65	0	135.69
KT5	Disturbed forest	92.42	0.82	8.1	0	101.34
KT6	Undisturbed swamp forest	165.85	2.57	10.99	1.78	181.19
KT7	Disturbed forest	93.96	2.18	2.42	0	98.57
KT8	Disturbed forest	128.84	2.45	0.99	0	132.28
KT9	Disturbed forest	90.81	1.31	0.36	0	92.47

*YEL data (2007) reprocessed (Van Belle and Hennin, 2008)

Tree Diversity. A total of 92 tree species were identified in 23 plots (4.6 ha) in the Tripa area. In undisturbed peat forest (4 plots), a total of 20 species were encountered, with average species numbers in each plot at 8. Secondary peat forest had less species, with 11 species found in 5 plots with an average of 5 species per plot. Species numbers in disturbed forest on mineral soils was higher: 79 species in 14 plots with an average of 12 species per plot.

Eugenia jambos, Eugenia curtisii, Litsea cubeba and Laurus nobilis were the most common species in the Tripa area, dominating all types of forest (Table 3).

Based on a list of trees used by orang-utan (Russon et al., 2007), all of the dominant tree species in Tripa were sources of orang-utan food. Analysis of tree diversity using the Shannon-Wiener Index showed that tree species diversity in Tripa was 3.61. High diversity of tree species particularly occurred in Kuala Seumayam (KT4, KT5, KT6, KT7, KT8, KT9), ranging 2.2–2.76, even though this area was categorized as disturbed peat forest. Unfortunately, this habitat is currently under threat of forest clearing.

Table 3. List of ten dominant tree species in three forest types in Tripa

Low density		High density		Secondary forest	
Species name	**Important Value Index**	**Species name**	**Important Value Index**	**Species name**	**Important Value Index**
Campnosperma sp.	15.48	*Eugenia jambos*	41.67	*Eugenia jambos*	58.28
Litsea cubeba	10.25	*Laurus nobilis*	36.98	*Eugenia curtisii*	29.27
Eugenia curtisii	9.84	*Areca* sp.	30.73	*Macaranga triloba*	19.46
Eugenia jambos	7.70	*Litsea cubeba*	11.46	*Litsea cubeba*	14.64
Laurus nobilis	6.95	*Myristica* sp.	7.29	*Ficus fistulosa*	17.14
Shorea sp.	7.96	*Litsea* sp.	6.25	*Quercus lutea*	17.14
Quercus lutea	6.29	*Eugenia curtisii*	5.73	*Knema laurina*	12.23
Hopea sp.	3.90	*Cinnamomun iners*	5.21	*Laurus nobilis*	11.02
Mezzettia parviflora	5.80	*Cryptocarya griffithiana*	5.21	*Camnosperma coriaceum*	9.82
Syzygium chloranthum	5.21	*Camnosperma coriaceum*	7.81	*Syzigium commune*	6.11

All growth stages (sapling (5–10 cm diameter), pole (10–20 cm diameter) and tree (> 20 cm diameter) of eight species were observed in each plot, indicating local regeneration, such as *Campnosperma auriculatum, Hopea* sp*., Laurus nobilis, Litsea* sp*., Macaranga triloba, Myristica* sp*., Phylanthus emblica and Shorea* sp*.* In contrast, 30 tree species (79%) in undisturbed peat forest were only found at the tree stage. Most of these are categorized as major timbers from the families Dipterocarpaceae, Lauraceae, Ebenaceae, Anacardiaceae, Annonaceae and Leguminosae.This indicated that these species did not regenerate well, which could be as result of some factors, such as no flower season in a long period and few or even no pollinator and dispersal agents. If this occurs in long period and threat of forest clearing continuously happens, the habitat of orang-utan in Tripa will vanish immediately.

Conclusion

Carbon stocks can be as an indicator of tree diversity. The carbon stocks in Tripa ranged from 28.5 ton ha^{-1} from agroforest to 193 t ha^{-1} in undisturbed forest. The swamp forest of Tripa is rich in tree species of food source for orang-utan. The large trees that orang-utan needs to construct nests are associated with high carbon stock. Direct human disturbance rather than shortage of food trees may be the primary constraint to orang-utan.

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