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Proceeding of International Symposium on

Wild Fire and Carbon Management in Peat-Forest in Indonesia

24-26 September 2013, Palangka Raya, Indonesia

Collaboration among:

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Proceeding of International Symposium on Wild Fire and Carbon Management in Peat-Forest in Indonesia

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Editors:

Mitsuru Osaki
Hidenori Takahashi
Toshihisa Honma
Takashi Hirano
Hiroshi Hayasaka
Takashi Kohyama
Shunitz Tanaka
Kazuyo Hirose
Hendrik Segah
Satomi Shiodera
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Joeni Sri Rahajoe
Orbita Roswintiarti
Ardianor
Salampak Dohong
Muhammad Evri
Biatna Dulbert

Hokkaido University, Palangka Raya University,
BSN, BPPT, LIPI, LAPAN,
Minister of Forestry
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Preface

In Southeast Asia, peatlands cover more than 26 million hectares (69% of all tropical peatlands), at altitudes from sea level to about 50 m above, mostly near the coasts of Sumatra, Kalimantan, West Papua, Papua New Guinea, Brunei, Peninsular Malaya, Sabah, Sarawak and Thailand (Page et al., 2004; Wosten et al., 2008). There are approximately 6 million hectares of peatland in Kalimantan (RePPProT, 1990; Radjagukguk, 1992) with a thickness varying from 0.3 m to 20 m (Anderson, 1983).

Natural lowland tropical peatlands are dominated by trees (peat swamp forest) and are important reservoirs of biodiversity, carbon and water. Tropical peat swamp forests in their natural state make an important contribution to regional and global biodiversity (Andriesse, 1988; Page and Rieley, 1998) and provide a vital, but undervalued habitat, for rare and threatened species, especially birds, fish, mammals and reptiles (Ismail, 1999). The increased awareness of these CO2 emissions has created strong political support for reducing deforestation and peatland degradation (REDD: Reducing Emissions from Deforestation and Degradation, UNFCCC, 2007), specifically in Indonesia that is responsible for the bulk of the emissions (Hooijer et al., 2006).

The “Wild Fire and Carbon Management in Peat-Forest in Indonesia” project has been conducted by JST-JICA in conjunction with Indonesian authorities to initiate a carbon management system in the peatlands of Central Kalimantan since 2008. Since remarkable progress has been made on the project, after 1st JST-JICA International Workshop “Wild Fire and Carbon Management in Peat-Forest in Indonesia” held at Jakarta (5-6 March 2009), the 2nd International Workshop (Palangka Raya, 28-29 September 2010) and 3rd International Workshop (Palangka Raya, 22-24 September 2011), International Symposium (Bogor, 13-14 September 2012), the 4th International Workshop 2013 had been held at Palangka Raya, 24-26 September 2013, to share updated information, experiences on project activities and other special sessions such as recent forest and climate change activities in Indonesia (REDD+ and MRV system), capacity building & networks, etc.

The Objectives of the Workshop are:
(1) Synthesize knowledge on past, present and future trends relating to wildfires and the carbon management of peat-forest.
(2) Provide information on the possible impacts of climate change, as well as guidance for stakeholders in the area of planning, implementation and scenarios (REDD-plus, MRV system, etc.).
(3) Compile a roadmap that provides a short to long-term vision on research needs (capacity building, networks, etc).

Below is the agenda of The 4th International Workshop on "Wild Fire and Carbon Management in Peat-Forest in Indonesia".

Tuesday/24th September, 2013

- Session 1 (FF) - *Remote Sensing, Carbon And Ecosystem Management Of Tropical Peatland*
- Session 2 (CA) - *Evaluation Of Carbon Storage And Carbon Flux Of Tropical Peatland*
- Session 3 (CM) - *Sustainable Management Of Carbon, Biodiversity & Ecosystem Of Tropical Peatland*
- Session 4 (PM) - *Integrated Tropical Peatland Management*

Wednesday/25th September, 2013

- Special Session 1- *Redd+ Function On Conservation And Rehabilitation Of Peatland*
- Special Session 2 - *Novel Technology For Peatland Ecosystem Evaluation*
- Special Session 3 - *Evaluation And Management Of Carbon-Water-Biodiversity System In Kalimantan, Indonesia*
- Special Session 4 - *Agroforestry And Social Forestry*
- Special Session 5 - *Collaboration With Other Projects In Indonesia*
- Special Session 6 - *Kalimantan University Network*
- Poster Award Ceremony

Finally, we would like to extend our sincere appreciation to the invited speakers (oral and poster presentations), session chairs and all participants. We are grateful to the Indonesian Institute of Sciences, JST-JICA,Workshop`s Steering Committee and Organizing Committee; for their kindness contributions and support to the success of this important workshop.

Sapporo, 1 February 2014

Prof. Dr. Mitsuru Osaki
Editor-in-Chief

Contents

Peatland mapping methodology

Mitsuru Osaki[1)] and Kazuyo Hirose[2)]

1) Hokkaido University
2) Japan Space System

I. Introduction

The better management of peatland forests, in particular, can make a substantial contribution to reducing atmospheric greenhouse gas concentrations in countries with significant peat forest carbon stocks. At the global level, in total peatland covering about 3,8 million km^2; about 3% of the global land surface. Peatland store more carbon than any other forest types, and their degradation results in larger emissions than from any other ecosystem. About 30 countries are responsible for the largest greenhouse gas emissions from peatland (Joosten, 2009), including many non-Annex I countries. The majority of the 130 million hectares of peatland in non-Annex I countries are naturally forested, and contain about 100 billion tonnes of carbon - most of which is in their soils. When the peatland are drained the carbon is released and emissions are ongoing until rehabilitation takes place.

Since 1990 peatland emissions have increased in 45 countries of which 40 are non-Annex I countries. Indonesia, Malaysia and China are some of the countries with the highest emissions from drained peatland among non-annex 1 countries. The emissions from peatland in non-Annex I countries through drainage and peat fires causes an annual of estimated 1.2 billion tonnes of carbon dioxide. In Southeast Asia for example in the last 20 years, more than 12 million ha has been drained; and more than 3 million ha has been burnt (especially during el-nino droughts. The recent decline of peatland forests in the region is twice the rate of decline of other forests. Under LULUCF of the Kyoto Protocol a new accounting activity is proposed for the second commitment period to provide incentives to reduce emissions from drained peatland in Annex-I countries. For non-Annex I countries REDD should provide such incentives.

II. Peatland mapping assessment

The largest area of tropical peatland at the present time exits in Southeast Asia (Figure 1), moreover they are found largely in Indonesia (predominantly Sumatra, Kalimantan and West Papua), Malaysia (Peninsular Malaysia, Sarawak and Sabah), Brunei and Thailand (Whitmore 1995, Page et al. 2004). In Borneo, peat swamp forest is distributed along the coasts of Sarawak, Brunei Darussalam, Sabah and Kalimantan on low-lying, poorly-drained sites and exist further inland than its neighboring beach forest and mangrove forest formation. Over past 4500 years, peat has accumulated as much as 20 m in some areas (Phillips 1998).

The tropical peat swamp forest is important as not only for its wealth of diverse bio-resources but also its huge carbon pool (Tawaraya et al. 2003). Tropical peat swamp forests and deforested peatland are important stores of carbon whose release in large quantities through burning can contribute significantly to climate change processes. Available ground information from field and aerial survey (airborne, and satellite sensing) indicated that the combination of human activities (land clearing, illegal logging, etc.) and forest fire induced the land-cover change in peatland areas (Putra et al. 2008).

Fig. 1: Map of peatland in South East Asia. The map <u>*illustrates*</u> that most peatland are distributed on the islands of Sumatra and Borneo (Kalimantan, Sabah, Sarawak and Brunei) and in Peninsular Malaysia (*Source*: Whitmore 1995)

Indonesia is charting a green growth plan which will ensure sustainable economic growth with smaller carbon footprint. Total amount of CO_2 emission in 2005 from Indonesia is 2.1 Gt, and 37.5% is from peatland. Ironically, the CO_2 emission in Indonesia is estimated to grow from 2.1 to 3.3 Gt from 2005 to 2030. Therefore, the reduction of CO_2 emission from peat is a key factor to contribute on REDD.

Indonesia has collected many data (such as land cover change, forest management, biomass above ground, biomass below ground, forest types, forest growth), but significant gaps exist to reach national monitoring system. The data of peatland area in Indonesia is also available as presented in the Figure 2. The differences of result and data uncertainties may stem from different assumption, methods, and technology used. The different organizations may use different methodologies and sources which contribute the different estimation, such as estimation of carbon emission.

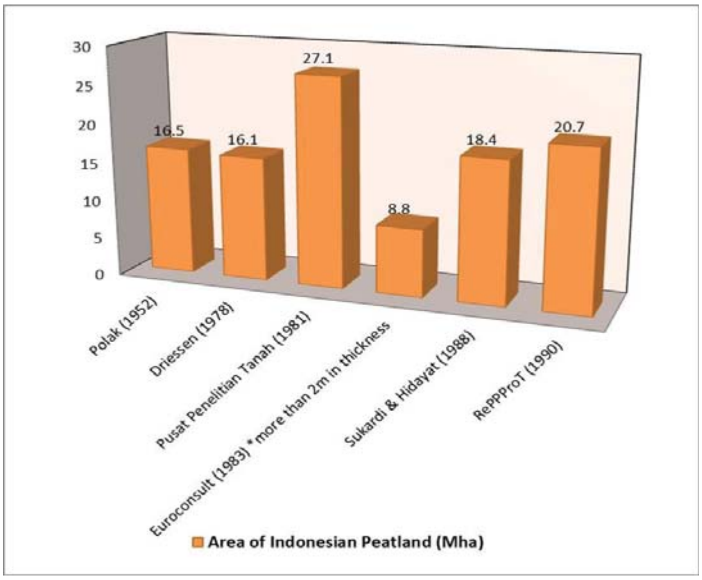


Fig. 2: Peatland area in Indonesia (in million ha)

The conservation and restoration of peatland can provide a major contribution to the climate change mitigation. Improving guidance and capacity for reporting of peatland emissions will prove valuable to the current negotiations towards the successful of REDD program. However, to can estimate the CO2 emission from peatland, and to can make the policy in the national scope for the climate change adaptation and mitigation on peatland, the definition of tropical peatland is very important. This will bring with the same understanding, and will make it easier to get the same view of thinking to problems that occur related to peatland in Indonesia.

2.1. Peatland Mapping by Wetlands

Moratorium Map was assessed to compare with Wetlands International Peatland map published in 2004 (Hirose et al, 2012). Moratorium Map and Wetlands International peatland map are shown in Figure 3. Differences between both maps are indicated by red and yellow circles on Figure 4. Red circles show a total of about 125,000 ha of decreased areas from Wetland International map to Moratorium Map. Yellow circles show a total of about 35,000 ha of increased areas from Wetland International map to Moratorium Map. Those differences might have been considered with existing license and newly issued license areas.

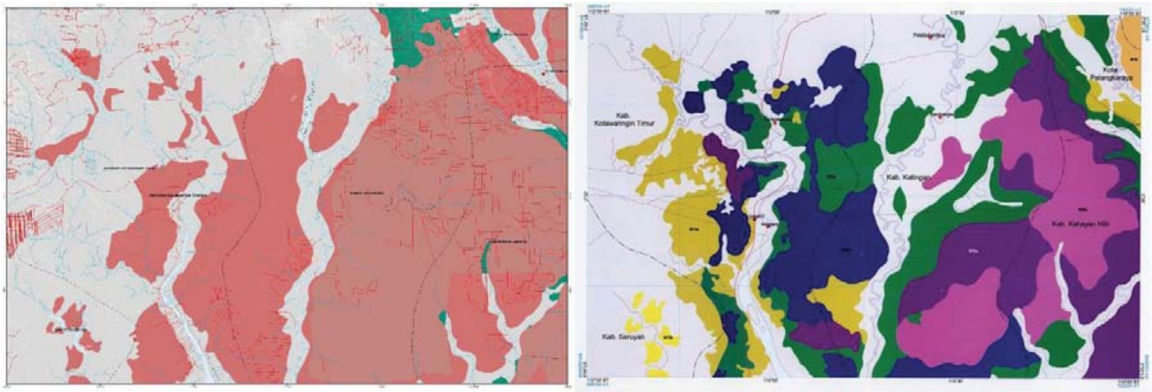


Fig. 3: Moratorium Map (left) and Wetlands International peatland map (right) for Central Kalimantan (Map sheet No. 1613, 1:250,000 scale)

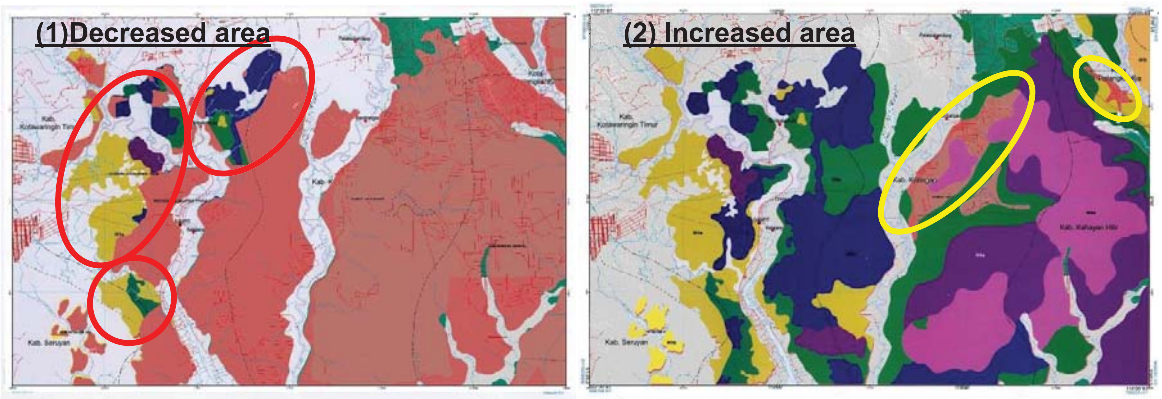


Fig. 4: Example of differences between Moratorium Map and Wetlands International peatland map (*Left*: Decreased area on Moratorium Map, *Right*: Increased area on Moratorium Map)

2.2. Gap Analysis of Peatland Mapping in Indonesia

Among the 20.2 million hectares of peatland, only 4.2 million hectares of peat covered by the moratorium is under primary forest cover. Moratorium is a temporary suspension during the two years to issue a new permit, which is valid from date of issuance of Presidential Decree on May 20th, 2011. This moratorium is applied on new licenses in the primary natural forests and peatland. Imposed a moratorium on new licenses in the primary natural forests and peatland are located in Indonesia, both in the forest (forest conservation, protection and production) and other area/non-forestry aquaculture area. The location of primary forests and peat lands refers to the indicative map of the new license suspension.

Since different extents of peatland have been reported using different sources, Wetlands International compiled existing available peatland data for Sumatra, Kalimantan and Papua to summarize existing survey data from a number of relevant institutions in Indonesia (Wetlands International, 2008).

2.3. Verification of Peat Map and Problems Extraction

Although Wetlands International had compiled existing all data, further presice data review and compiling all available data are necessary by all Indonesian and international experts for applying peat definition which is proposed in this policy brief. For achieving the remarkable improvement of peatland map, short training is necessary for the experts to understand standard methodology. It is important to create a peat mapping database that contain of spatial and temporal data for the key parameters from the field measurement. These parameters should be measured using the standard methods with high level of accuracy.

In May 2010, the governments of Norway and Indonesia signed a Letter of Intent (LoI) for a REDD+ partnership that would contribute to significant reductions in greenhouse gas emissions from deforestation, forest degradation and peatland conversion in Indonesia. Phase 2 of this agreement requires Indonesia to implement a two-year moratorium to suspend all new concessions for the conversion of peat and natural forests. The wider goal of this moratorium is to create a baseline on critical elements of forests, peatland and 'degraded lands' that is strategic to the effective implementation of a nationwide REDD+ strategy in the future.

III. Proposed peatland mapping methodology

3.1. Sampling method

To complete moratorium map for peatland, it is urgently to survey from river-side of peatland, because river-side seen is uncertain and unclear in peat quality, peat depth, and geomorphology. Thus, several elements of peatland should be surveyed from river-side and sampling points should be denser in river-side area than peat-dome area (Figure 5).

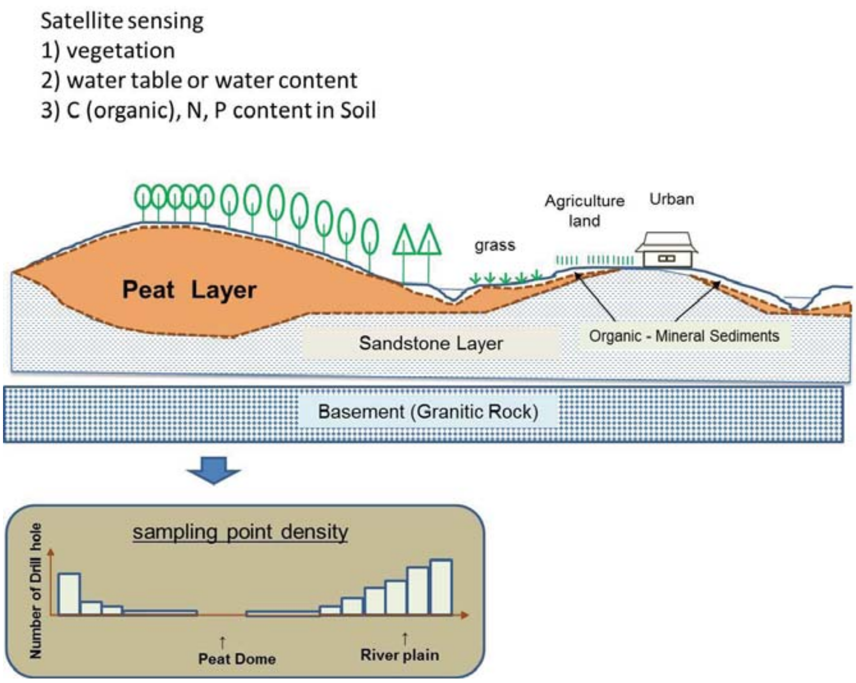


Fig. 5: Peatland schematic

3.2. Carbon Mapping in Peatland

Tropical peat ecosystems are considered to play key roles not only in the storage of carbon in forests and peat, but also in controlling water resources and in preserving bio-resources and biodiversity. Once tropical peatland have been disturbed by deforestation/degradation and the digging of canals, the water table in the peat soil and the water content at the peat surface both decrease. Then, large amounts of the carbon contained in peat soil are lost through peat fires, respiration of the microbial fauna contained in peat, and the runoff of black carbon (Dissolved Organic Carbon, DOC) into rivers (Figure 6). Also tree growth decreases and tree mortality increase by lowering water table, which cause seriously to degrade Forest (Unpublished data), and decrease biodiversity.

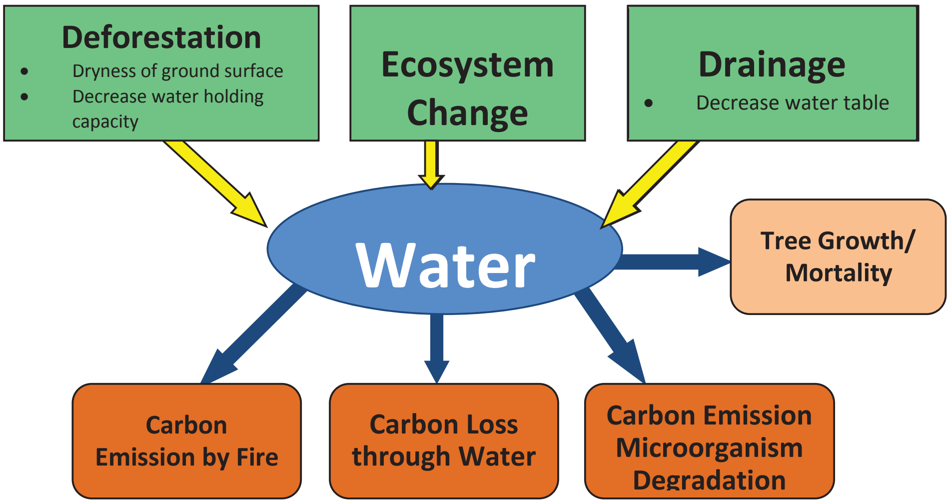


Fig. 6: Key element on carbon flux and loss from peatland
(cited from Mitsuru Osaki et al. Springer, 2012)

3.3. Water Table Monitoring and Mapping

3.3.1. Estimation of Water Table by Satellite Sensing

The ground water table is key to estimate peatland ecosystem, which is expected to be an indicator for better wild fire occurrence, peat degradation, carbon loss thorough DOC (Dissolve Organic Carbon), and plant growth. Firstly, modified Keeth-Byram drought index (mKBDI) was computed by incorporating satellite-based precipitation GSMaP and MTSAT land surface temperature (LST). Secondly peat soil moisture (PSM) was retrieved by normalized polarization index with vertical and horizontal polarization of passive microwave sensor AMSR- E and it was related with near surface ground water table (GWT). Thirdly initial value of GWT was estimated by PSM and a time-series of calibration was carried out between mKDBI and ground-based GWT measurements at drained forest (DF), un-drained forest (UDF) and drained burnt forest (DBF) respectively. It was found that KBDI was well calibrated with GWT at the above mentioned three measurement sites and a very good indicator for peat fire risk zone mapping at forested peatland. Figure 7 shows a framework of ground water table (GWT) mapping using drought index. Five types of data are prepared including; (a) Global Satellite Map of Precipitation (GSMaP), (b) MTSAT IR1 and IR2 for land surface temperature retrieval (Oyoshi, 2010), (c) In-situ ground water table measurements (GWT) (Hirano, 2005), (d) AMSR-E VV and HH polarization data in 23.8 and 36.5GHz to compute normalized frequency index (NDFI) (Takeuchi, 2009) and (e) MODIS host spot product (MOD14) to map wild fire occurrence at forested peatland (W. Takeuchi et al. 2012).

Figure 8 shows a comparison of in-situ measurement of ground water table (GWT), modeled GWT and precipitation as a reference in drained forest (DF), un-drained forest (UDF) and drained burnt forest (UBF). Overall a modeled GWT at DF, UDF and DBF shows very good time-series of behaviors along with that of in-situ measurement. A modeled GWT is more sensitive to precipitation resulting in a drastic water table rise-up around DOY 220 and 280 for DF site, DOY 200 and 230 for UDF site and DOY 220 for DBF site. This implies that a daily precipitation r is overestimated in Equation 1 and more calibration data is indispensable to get a better result.

Assuming that the peat decomposition process would be mitigated by rewetting, carbon emissions and subsidence could somewhat be reduced in existing agricultural plantations by keeping the water table as high as possible. However, the relationship described by Couwenberg et al. (2010), in which subsidence increases with drainage depth, is valid only for drainage depths lower than 50 cm – which is a minimal drainage depth for many agricultural uses. In addition to controlling drainage, minimal use of nitrogen fertilisers will restrain nitrous oxide emissions, and potentially peat decomposition as well.

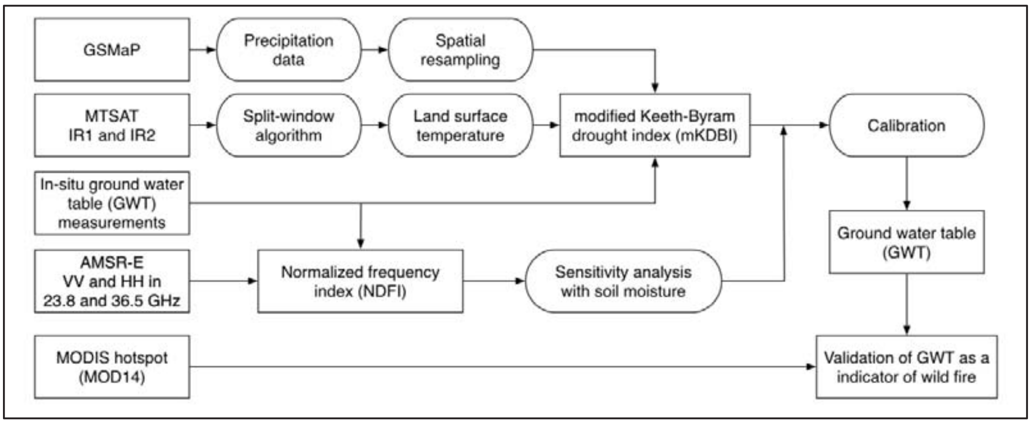


Fig. 7: Flowchart of a framework of ground water table (GWT) mapping using drought index (From Dr. W.Takeuchi)

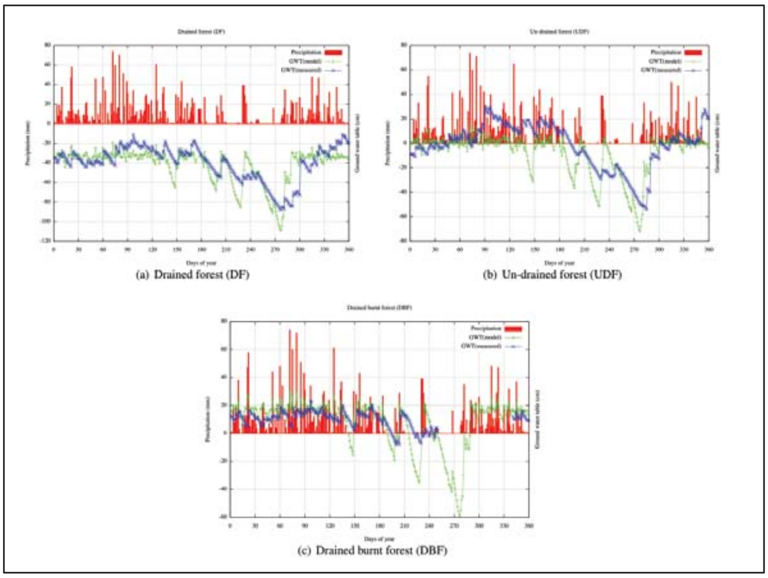


Fig. 8: Comparison of In-situ measurement of ground water table (GWT), modeled GWT and precipitation as a reference in drained forest, un-drained forest and drained burnt forest (From Dr. W.Takeuchi)

Figure 9 shows a comparison of ground water table map and land cover classification in Oct. 10, 2007. Lower GWT area shown in Figure 9-(a) mainly corresponds to croplands shown in Figure 9-(b). It is very interesting that the forested area in the Southeast of our test site has very low GWT values less than 1.5m in contrast to that of in the Northwest where GWT is higher than 0.5 m.

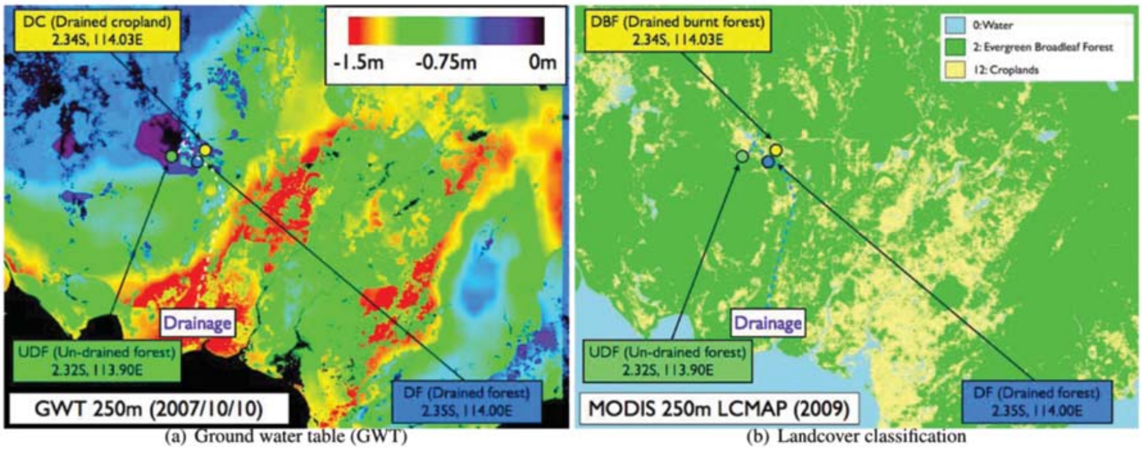


Fig. 9: Comparison of ground water table map and land cover classification in Oct. 10, 2007 (From Dr. W.Takeuchi)

3.3.2. Carbon Loss Estimation using Water Table Map

Because a strong relationship between deep peat fire and the water table has been confirmed that deep peat fires become more frequent and peat soil respiration increases (H. Takahashi 2003, T. Hirano et al. 2007 and 2009). The ratio (RE/GPP) of RE (Respiration in Ecosystem) to GPP (Gross Photosynthetic Product in Ecosystem) against groundwater level is plotted in (Fig. 10). One negative line ($r^2 = 0.38$) explains the relationship for both the un-drained swamp forest (UDF) and drained forest (DF) sites. Another negative linear relationship ($r^2 = 0.69$) was found for the burnt forest after drainage (BD) site. RE depends on GPP, because vegetation respiration consumes photosynthates. Thus, the ratio of vegetation respiration to GPP can be assumed to be almost constant. If so, variation in RE/GPP is mainly related to that of microbial respiration. Therefore, the negative linear relationships indicate that microbial respiration or peat decomposition was enhanced as groundwater level decreased.

Therefore, the following two methods were proposed for estimating and predicting carbon fluxes and balances; one is the direct measurement of carbon flux, and the other is simulating the carbon flux using either a water statue such as the water table, the moisture content in peat soil, or evapotranspiration in peatland. In conclusion, the carbon and water model is essential to carry out the MRV system in tropical peat and forest.

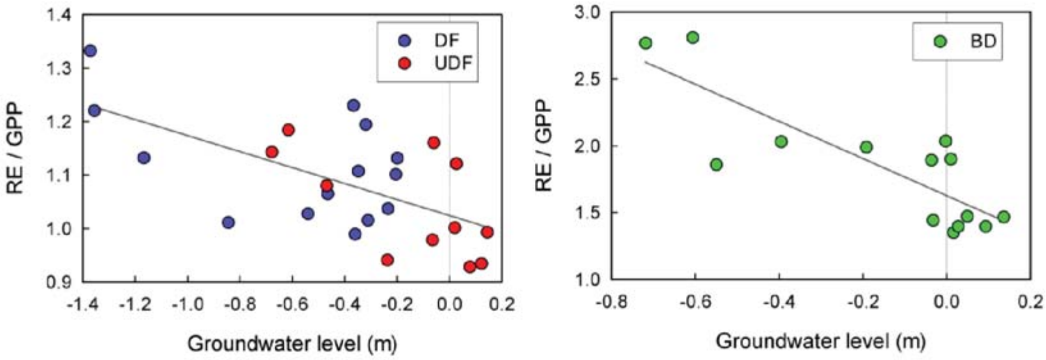


Fig. 10: Relationship between the ratio of RE to GPP and groundwater level on a monthly basis from April 2004 to May 2005. UDF: Un-drained Forest, DR: Drained Forest, and BD: Burned Forest (cited from Mitsuru Osaki et al. Springer, 2012)

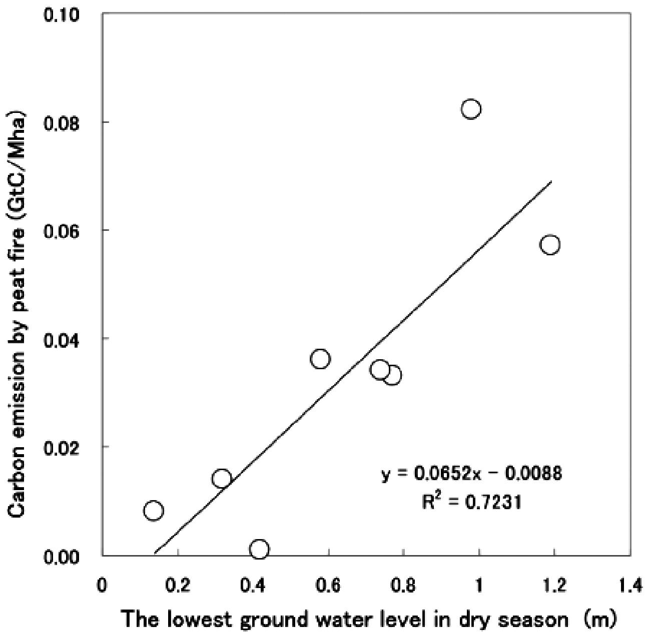
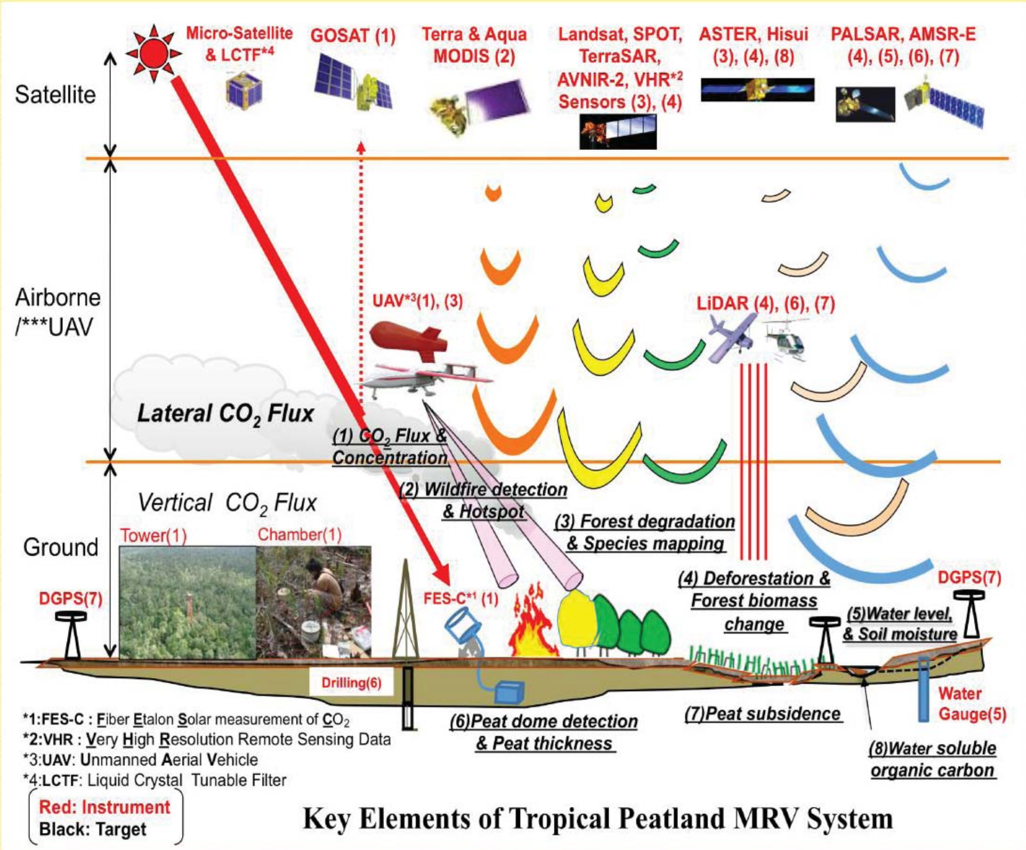


Fig. 11: Relationship between the lowest ground water level in peatland and total amount of carbon emission in Mega Rice Project area (cited from Mitsuru Osaki et al. Springer, 2012)

Thus, carbon balance in the ecosystem is estimated as flux/loss of carbon, which is affected by the water level or content in peat soil. Water level has an effect on biodiversity through peat degradation, fire occurrence, and aquatic ecosystem changing. Carbon sensing network is a most important technique; however, as maintenance of the carbon sensing network is very costly, a more simplified model for carbon balance is required. From our long-term monitoring of carbon flux and the water table, it became clear that the water table is most important factor related to carbon loss by fire and respiration. Therefore, the Carbon-Water Model became the final Model for MRV and estimation on biodiversity.

BOX 1: Key Elements of Tropical Peatland MRV System

As carbon balance in peat is strongly affected both by the water statue and the ecosystem (vegetation, farming system and topography), the carbon budget should be estimated as a multifunctional system within the carbon-water-ecosystem. The MRV Unit will manage a Data Sub-Unit and a Training Sub-Unit. To successfully achieve the "**M**easuring, **R**eporting and **V**erification" roles, an MRV system comprised of the following three sections was proposed. The building of a monitoring and sensing system for the carbon-water-ecosystem is urgent and necessary to be able to apply new sensing technologies using different altitude levels such as satellite, aircraft, and ground. The MRV Section has a final role to store and accumulate data in a standardized GIS format in the Data Sub-Unit. MRV Section is carried out mainly by sensing via satellite and airplane (a) and monitoring by ground tools. Monitoring/Sensing targets are (1) CO_2 concentration, (2) Hotspot(s) of peat fire, (3) Forest degradation and species mapping, (4) Forest biomass and biomass loss, (5) Peat-subsidence, (6) Water level and soil moisture, (7) Water soluble organic carbon, and (8) Peat thickness.



3.4. Ecosystem Mapping on Peatland using Advanced Satellite Sencing

Remote sensing is the most useful tool to observe earth seuface and a lot of advanced satellite utillization has been proposed. However, only few methodologies have been proposed for peatland boundary delineation as follows.

3.4.1. Combiation of NDVI and Ts

Shimada (2003) found significant relationship between classified phenology types of peat swamp forest and peat volume in Central Kalimantan based on Normalized Difference Vegetation Index

(NDVI) and Surface Radiative Temperature (Ts) of NOAA-AVHRRR data (Figure 12). Therefore, significant improvement of existing peatland maps is expected significantly for entire peatland area in Indonesia within short periods of time.

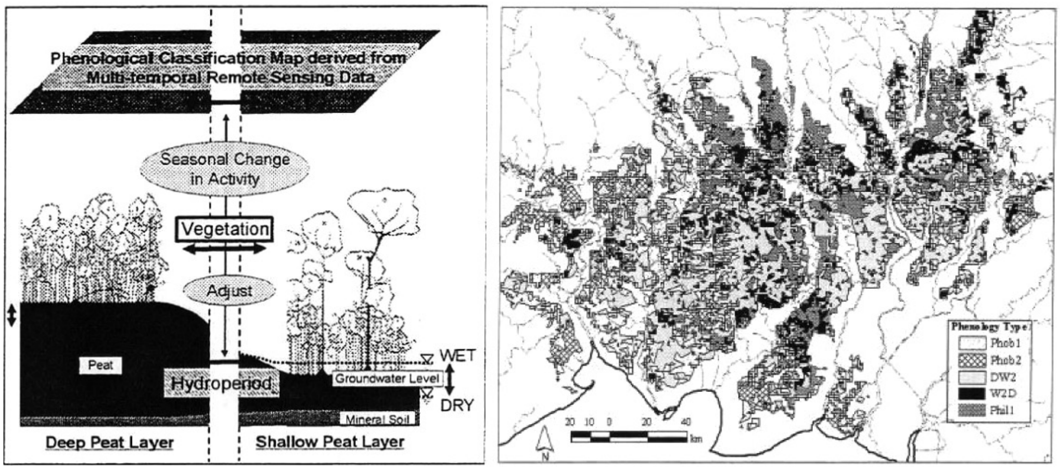


Fig. 12: Schematic hypothesis model for detecting the difference between the deep and the shallow peat layered swamp forest (*left*), Classified map of phenology types peat swamp forest in Central Kalimantan (*right*)

3.4.2. Satellite Data Utilization (Hyper Spectral Data)

Earth Remote Sensing Data Analysis Center (ERSDAC) conducted for peatland forest mapping in Central Kalimantan using Hyper Spectral Data on July 2012. 124 bands data were acquired from 400nm to 2500nm with 10-15nm band resolutions by Airborne Hymap Sensor. Result of data analysis showed different peat swamp forest types and it is expected to discriminate specific forest types which is closely related to different peat swamp condition such as pH, peat depth and elevation. Also data by nallow spectral band resolution (10-15nm) enables to estimate presice water leaf content of peat swamp forest which suggests ground water level and peat depth (Figure 13).

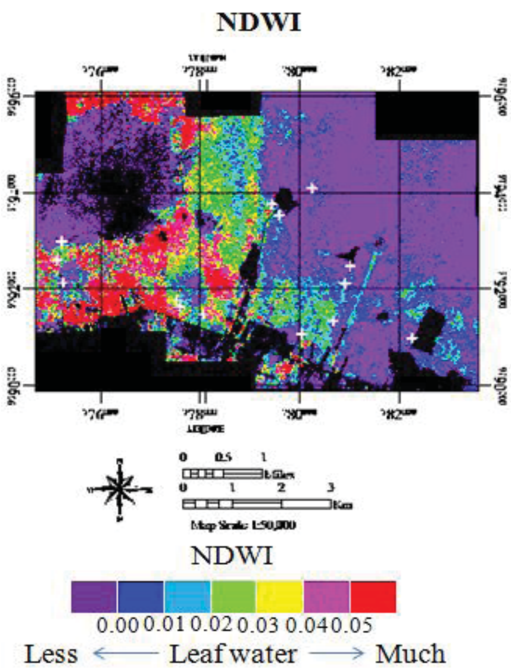


Fig. 13: Presice leaf water content map by Normarized Difference Water Index (NDWI) of Hymap data

3.5. Mapping of Social Activity on Peatland

Peatland ecosystem is the one of unique and vulnerable ecosystem to climate change. Therefore, comprehensive and long term research and development should be continued to understand its complicated system by scientific experts with local stakeholders' assistance. In this context, capacity building for stakeholders is an important role to implement peatland mapping research and development.

Peatland area especially in Indonesia which content huge of forest carbon storage and it`s management (including REDD-plus programs, etc.) are part of mitigation responses to the climate change issue. It covers a very wide angle of scientific disciplines. Therefore, there are research and development needs for forest carbon management, such as: (1) Forest carbon accounting, (2) Forest measurements, (3) Carbon management technology, (4) Socioeconomic issues, (5) Decision-support systems, (6) Funding mechanism and benefit distribution, (7) Biodiversity and its conservation and valuation, and (8) Environment services.

The Feasibility Study (FS) survey for "Katingan Peatland Restoration and Conservation Project" has conducted in many areas of PT. Rimba Makmur Utama (PT RMU). As an output from the FS surveys, the monitoring plan for the future activity of "Katingan Peatland Restoration and Conservation Project" is developed as follows:

1. The Quality Assessment and Quality Control guidelines are need to be proposed.
2. Monitoring the project implementation.
3. The calculation of actual net GHG emissions avoided is based on data obtained from sample plots, regional literature values and methods developed in GPG-LULUCF (Good Practice Guidance for Land-Use, Land-Use Change and Forestry) to estimate carbon stock changes in the carbon pools and peat emissions.
4. Periodically monitoring the stratification of the project area.
5. Monitoring the leakage due to activity displacement and accounting it in order to calculate the net GHG emissions avoided.
6. When a project is undergoing validation and verification, non-permanence risk analysis shall be conducted by both the project developer and the verifier at the time of verification in accordance with the VCS (Verified Carbon Standard) tool for AFOLU (Agriculture, Forestry and Other Land-Use), Non-Permanence Risk Analysis and Buffer Determination.

Since fire is commonly used to clear land, prepare land between rotations, and burn residues, it is also important to work with the local communities to identify alternatives to fire use. More education is also necessary to prevent accidental fires from negligence. In the past, fire has been used to protest or draw attention to land tenure disputes; therefore resolving these social issues is also necessary to reduce fire risk. It is important to bear in mind that peat substrate oxidation will continue from drained, converted peatland even if fire is prevented, resulting in high net carbon emissions.

3.6. Mapping of CO2 Emission using simulation Model

Emissions in peatland normally occur due to fire, man-made drainage, and through extractive or conversion activities, and occasionally could occur due to extended droughts. The system of monitoring should have built-in checks and take a hierarchical approach starting with satellite imagery, aerial surveys, and then ground patrols. Due to hydrostatic pressure, canals can have impacts on draining peat forest several kilometers away, causing subsidence, oxidation, and the eventual collapse of peat domes. To avoid this issue, the methodology calls for a buffer that excludes man-made canals from the carbon accounting area and monitoring will need to track whether any canals are being built in this buffer. Monitoring should be conducted by a professional team consisting of a coordinator, a field team, and a GIS technician. All monitoring activities should be implemented using Standard Operational Procedures (SOPs) and all personnel should be trained permanently to ensure the data quality.

The current knowledge is sufficient to assist in management decisions for any peatland managers and policy makers, including broad mitigation strategies for intact peat forest, drained and degraded forest, and agricultural lands on peat. The action of avoiding disturbance, deforestation or conversion of intact forest is the most effective way to prevent permanent and large-scale net carbon losses from peatland and ecosystems.

Methods for studying carbon dynamics in peatland and mangroves can clearly be improved in several areas, such as by using standardised methods and protocols which would greatly improve the comparability of results between studies and reduce confusion. Standardised methods would be required, in particular, for covering the high spatial heterogeneity of soil surface emissions in forests (Hirano et al. 2007) and excluding root respiration from closed-chamber flux measurements of CO_2 (Figure 14). Clear protocols would also help to ensure that methods are applied uniformly by different scientists working within the same project.

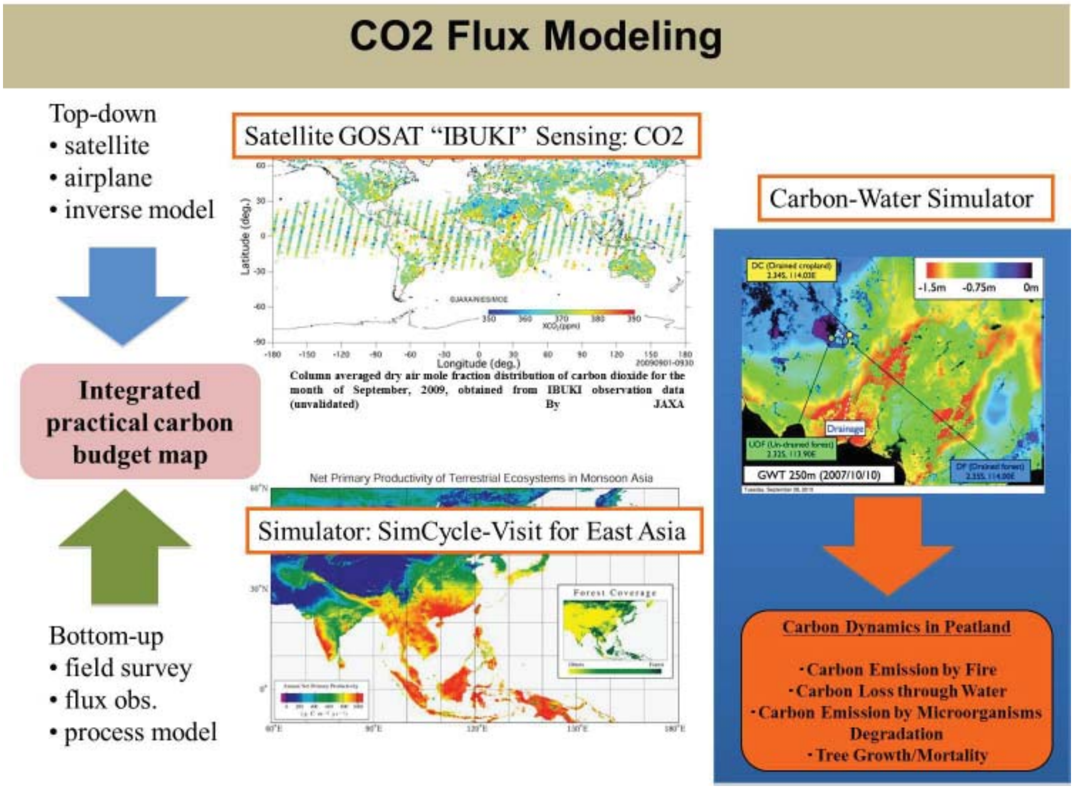


Fig. 14: CO_2 flux modeling (cited from Mitsuru Osaki *et al*. Springer, 2012)

Reference

Mitsuru Osaki, Takashi Hirano, Gen Inoue, Toshihisa Honma, Hidenori Takahashi, Noriyuki Kobayashi, Muhammad Evri, Takashi Kohyama, Akihiko Ito, Bambang Setiadi, Hozuma Sekine and Kazuyo Hirose: Sensing/monitoring networks on carbon balance and biodiversity in tropical peatland. In "The Biodiversity Observation Network in the Asia-Pacific Region", eds. by S. Nakano, T. Yahara, T. Nakashizuka, p.349-374, Springer, Tokyo/Heidelberg/New York/Dordrecht/London (2012)

ANNEX: Proposed research program on peatland and peatland mapping based on Bandung meeting

No	Activity/Program	Main Objectives	Specific Objectives	Indicator of achievement/ Output	Linking with policy
1	GPR Survey of Tropical Peatland in Indonesia	1. To acquire new knowledge and new information regarding tropical peat, especially in its physical as well as chemical properties. 2. To provide an alternative method in detecting peat depth and peat volume in tropical peat environment.	1. To verify the suitability of GPR in the detection of peat depth and in estimation of peat volume in tropical peat environment.	1. GPR surveys are conducted timely in accordance with technical requirements and specification 2. GPR data are processed accordingly with appropriate software and verified by core data. 3. Approved by DNPI, the results of GPR survey are publishable in international referred journals. **Output:** 1. Depth profile of GPR lines that show verified peat depth. 2. Estimated peat volume in each peatland site. 3. Protocol for GPR survey in tropical environment	Better estimate of peat depth and peat volume would improve the quality of decision and policy on peat and peatland issues.
2	A multi scale and multi sensor remote sensing approaches to inventory peatland in Indonesia	The research aims to inventory peatland in Sumatera, Kalimantan and Papua using multi-scale and multi-sensor remote sensing data	1) To develop standard procedure of digital image processing based on remote sensing data from different sources 2) To integrate multi-sensor remote sensing data with developing specific algorithms and methods 3) To generate Indonesia peatland spectral library	- The research result is providing better accuracies (map); - International publications (seminar, journal) - The integrated methods will be a standard operating procedure; - Peatland spectral library will be the first library in understanding peatland systems **Output:** 1) Peatland Distribution Map 2) Indonesia Peatland Spectral Library	- Community development (continuing education); economic growth; sustainable development; public domain - Capacity building; conservation; - Scientific knowledge dissemination (books)

3	Assessment of Social and Economic Dynamic at Village Level	To assess social and economic dynamic at village level	1. Village map with scale of 1:5.000 2. Land Use Management. 3. Green business opportunity for local people. 4. Support for climate change program.	1) Map collation - Base map with scale of 1:50.000 for Sumatera and Kalimantan - Base map for 1:100.000 for Papua. - Parcel map or land. - Land suitability map. 2) Social economic and anthropology survey. - Social and economic data attributes. - Social and economic spatial data - Village cultural data. 3) Village survey border (participatory mapping) - Village boundary pillars and village border coordinates. 4) Survey of land tenure area (participatory mapping) - Land ownership data 5) Airborne Survey - Topography map and 3D map. 6) Data Integration - GIS Database	
4	Develop ICT in Indonesia Climate Change Center	To develop Indonesia Climate Information System	To develop Data Center	**General Objective:** - Data Center - Climate Database - Web GIS Appl./ - Indonesia Climate Portal - Integrated DMS - Integrated w/ NSDI - Climate Awareness	1) Provide Accurate Spatial Information on Policy Development 2) Get Involve on Policy Dev 3) Support on Policy Dev

				Specific Objective: ICT Infrastructure Initial Climate Database Skilled SDM **Output:** 1) Data Center; 2) Peatland & Peatland Mapping Portal 3) Skilled Human Resources 4) Socialization	
5	NATIONAL PEATLAND GEODATABASE DEVELOPMENT	To update National peat land map to support one map reference / base map	1) Providing peatland map to support one map policy (UKP4) and supporting the Presidential Decree 61/2011 on reducing GHG through development of long-term policy and strategy for sustainable peatland management with the availability of accurate peatland maps 2) Supporting measureable, reportable and verifiable (MRV) monitoring system on peatland. 3) Supporting the strategy for peatland emission reduction and development of emission factors .	1) Preparation of guidelines and peatland mapping standard with scale 1:250.000 2) Peatland maps (1:250 000) for Sumatera and Papua 3) Development and updated peatland database 4) Carbon management and strategies of emission reduction on peatland areas. 5) Land use and land use change in peatland 6) Land cover mapping and peatland fragmentation in Kalimantan by landsat archive 7) Training and capacity building for peatland mapping participatory **Output 1** Availability of peatland map of Sumatra and Papua with the scale of 1: 250.000 **Baseline:** Current spatial data lacks ground truth, and thus lots of deviation	- Provision of related to the definition, classification, methods, design of map layout, and index numbering - Provide the peatland map seamless - Provides peatland map to support one map reference for UKP4 activities and - Supports the Presidential Decree 61/2011 by development of long-term policy and strategy for sustainable peatland management with the availability of accurate peatland maps. - Support the Presidential Decree 71/2011 on inventory of GHG by accurate and rationale carbon stocks and GHG emission database under different types of peatland. - Supporting measureable, reportable and verifiable (MRV) monitoring system. - Provide the fragmentation map of peatland to comprehensively understand the ecological condition of peat

				between the map and actual field condition. In addition there is no delineation of degraded peatland in the current maps **Indicator:** 3 volumes of Atlas of degraded peatland, and land potential suitability and conservation areas **Target:** peatland atlas of Sumatra and Papua at 1:250.000 scale **Output 2:** development and updated peatland database **Baseline:** Limited data on peatland especially its characteristics, trigger factors for emission **Indicators:** Data house of peatland information **Output 3** Carbon management and strategies of emission reduction on peatland areas. **Baseline:** - High variation in temporal and spatial peat C stock and emission. - Very limited wall to wall analysis of GHG emission and strategies of emission reduction to support the implementation of RAN-GRK for voluntary market **Indicator:** A set of data and Report on GHG emission, REL and mitigation	

				options **Target:** Completion of mitigation options form peatland in one peat districts.	

Incentive of local community by payment for peat swamp ecosystem services on REDD+ and safeguard

Shigeo Kobayashi
Graduate School of Asian and African Area Studies, Kyoto University
46 Shimoadachi-cho, Yoshida, Sakyo-ku, Kyoto 606-8501 Japan
Tel: +81-75-753-7832, E-mail: skobayashi@asafas.kyoto-u.ac.jp

Abstract: The Ramseur treaty on wetland conservation was concluded as treaty in 1971. Wetland forests in the tropics have, however, been experiencing drastic land-use changes for easy access and utilization, which, together with tropical forest decline, has also been a focal point of global environmental issues. Rehabilitation of degraded wetlands has, nevertheless, hardly been attempted. LULUCF (Land-Use, Land-Use Change and Forestry) has been discussed as an agenda of IPCC since 2001. It is, therefore, urgently necessary to conduct research on land resource management option and local society empowerment for global-warming prevention in Southeast Asian wetlands. COP15 of Copenhagen Agreement was proposed REDD+□Reducing Emissions from Deforestation and Forest Degradation in Developing Countries(2009) and COP16 of Cancun proposal REDD+ with Safeguard (2010). Southeast Asia has the widest area of wetlands in which consist of mangrove, peat swamp and freshwater swamp forests are distributed in 28.3 million hectares compared with 3.5 million ha in Africa and 5.2 million ha in Latin America (Page et al. 2010). Indonesia is the fifth country for emission of GHG including peat fire by President Yudoyono. Therefore, I would like to discuss the safeguard related with PES. When undertaking activities referred to in paragraph 70 of this decision, the following safeguards should be promoted and supported such as (1) Action complement or are consistent with the objectives of national forest programme and relevant international conventions and agreements, (2) Transparent and effective national forest governance structure, taking into account national legislation and sovereignty, (3) Respect for the knowledge and rights of indigenous peoples and members of local communities, by taking into account relevant international obligations, national circumstances and laws, and noting that the United Nations General Assembly has adopted the United Nations Declaration on the Rights of Indigenous Peoples, (4) The full and effective participation of relevant stakeholders, in particular, indigenous peoples and local communities, in actions referred to in paragraph 70 and 72 of this decision, (5) Actions are consistent with the conservation of natural forests and biological diversity, ensuring that actions referred to paragraph 70 of and this decision are not used for the conversion of natural forests, but are instead used incentivize the protection and conservation of natural forests and their ecosystem services, and enhance other social and environmental benefits, (6) Actions to address the risks of reversals, (7) Actions to reduce displacement of emissions.

The unrecognized problem: will subsidence flood drained peatlands in Indonesia?

Aljosja Hooijer[1)], Ronald Vernimmen[1)], Budi Triadi[2)], Oka Karyanto[3)], Sue Page[4)]

[1)] Deltares, [2)] RCWR, [3)] UGM, [4)] University of Leicester
[1)] Deltares, Rotterdamseweg 185, P.O. Box 177, 2600 MH Delft, The Netherlands,
tel: + 31 (0)88 335 8273, aljosja.hooijer@deltares.nl
[2)] Puslitbang Air, Indonesia
[3)] Universitas Gajah Madah, Indonesia
[4)] Leicester University, UK)

Drainage of peatlands inevitably leads to subsidence, mostly caused by carbon loss. With few exceptions, this eventually leads to gravity drainage becoming impossible, as subsidence lowers the land surface to River or even Sea level resulting in flooding. Internationally, this loss of drainability has been the main reason why most countries have decades ago ended attempts to convert peatlands to drained agriculture, and often are now struggling to undo the damage at high costs. Recent pilot studies show that Indonesia will be no exception to this pattern: the mineral bottom below coastal peatlands is below Sea level in up to 50% of the area, and below high River levels in over 90%. With often only a few metres of peat thickness above River levels, and subsidence rates of 2-5 cm yr-1 depending on crops, water management and peat type, drainability problems can be expected within a few decades. Loss of agricultural production in some peatlands may start within 25 years, and in most peatlands is likely within 50 to 100 years. One would expect that in land use planning and economic cost-benefit analyses, the benefits of increasing agricultural productivity on peatlands in the short term should be weighed against the inevitable increase in water management costs and loss of production in the medium to longer term, but this necessity currently goes unrecognized in Indonesia. For such quantification, it will be necessary to have better maps of both peat thickness and peat surface elevation. We propose to include intensive studies of peat surface elevation, which is also a key to quantifying peat thickness, in research plans.

Keywords: tropical peatlands, drainage, subsidence, flooding

Introduction

Peatland drainage leads to subsidence, which in turn leads to reduced drainability, declining productivity and in lowland areas often eventually results in abandonment of land for agricultural production. There have been many documented cases around the world of subsidence exceeding 2 metres in a few decades and of subsidence over 3 metres within a century (Table 1). It is also known that the biological oxidation component of subsidence is highly temperature dependent and therefore higher in warmer climates (Table 1; Stephens et al., 1984). A number of studies confirm that subsidence rates in drained tropical peatlands in Malaysia and Indonesia are at the high end of the range found globally, at around 5 cm y-1 (Andriesse, 1988, Wösten 1997, DID Sarawak 2001, Hooijer et al., 2011; Hooijer et al., 2012, this conference), and report that this is caused mostly by biological oxidation with the physical processes of consolidation and compaction being major contributors to subsidence only in the first years after drainage. Due to the dominance in (sub) tropical peatlands of biological oxidation, which does not result in soil 'ripening' or 'maturation', no evidence is found of a substantial slowdown in subsidence rates in the long-term after the initial few years, until peat is depleted or lower peat layers with higher density or mineral content are accessed (Stephens et al. 1984, Hooijer et al. 2012).

Table 1 Subsidence rates in peatlands across different climate zone in the world. The highest subsidence rates are found in warmer areas.

Area (country)	**Area (km^2)***	**Drainage period (years)****	**Total subs. (m)**	**Ann. Subs. (mm/yr)**	**Av. Ann. Temp. (°C)**	**Ref.**
East Anglian Fenlands (UK)	1,276	130	3.9	30	9.0	Hutchinson, 1970
Dutch coastal plain (The Netherlands)	8,000	1000	2.0***	2	10.0	Unpublished results
Venice Watershed (Italy)	23	70	2.0	29	12.0	Camporese et al., 2006
Sacramento-San Joaquin Delta (USA)	1,000	160	1.0-8.0	6-50	15.9	Deverel & Leighton, 2010
Everglades (USA)	2,600	75	2.5	33	22.0	Stephens, 1956
Johor (Malaysia)	950	40	2.8	75	25.0	Wösten et al., 1997

* land use is foremost agriculture, with the exception of The Netherlands, where land use is pasture.
**These values all include the initial drainage period, in which subsidence is dominated by consolidation
***Average value, extremes up to 5 meter, and up to 12 meter if peat mining is included

Cumulative subsidence reported in peat in SE Asia of more than 3 metres in thickness over the first 5 years after drainage is between 1 and 1.5 metres. Over the first 25 years after drainage this is commonly around 2.5 metres. If peat depths and hydrology allow it, a loss in peat surface elevation of 6 metres is expected over 100 years, excluding the effect of fires which is a significant cause of peat loss in this region (Page et al. 2002). These numbers assume water table depths stay around 0.7 metres on average which is presently the norm in relatively well managed plantations in Indonesia (Hooijer et al. 2012). If water levels are lower, greater cumulative subsidence rates are expected; if they are higher subsidence would be reduced. However the effect of bringing up water levels is not as great as is sometimes assumed because other impacts of plantation development, especially higher soil temperatures, are also important controls on biological oxidation. Subsidence, and the accompanying loss of carbon to the atmosphere, is therefore inevitable consequences of deforesting and draining tropical peatlands.

There have been no studies to date of the longer-term effects of subsidence on future land drainability and agricultural productivity. From other regions, such as East Anglia in the UK (Hutchinson, 1970; Table 1), it is known that continued subsidence often eventually leads to gravity drainage becoming impossible if subsidence brings the land near sea level. Indeed, around the world this has been a major cause of abandonment of drained peatlands. The unsustainable outcome of peatland drainage has also been described for Indonesia in past decades, generally leading to the conclusion that areas with peat over 2 metres in thickness are unsuitable for conversion to agriculture (Andriesse 1988). This has however not stopped many millions of hectares of peatland being deforested and drained since 1990. In this paper, we assess how serious the problem of production loss on drained peatlands in SE Asia may become, by tentatively estimating the minimum area that may be at risk of loss of drainability or inundation, as well as the time that this development may take.

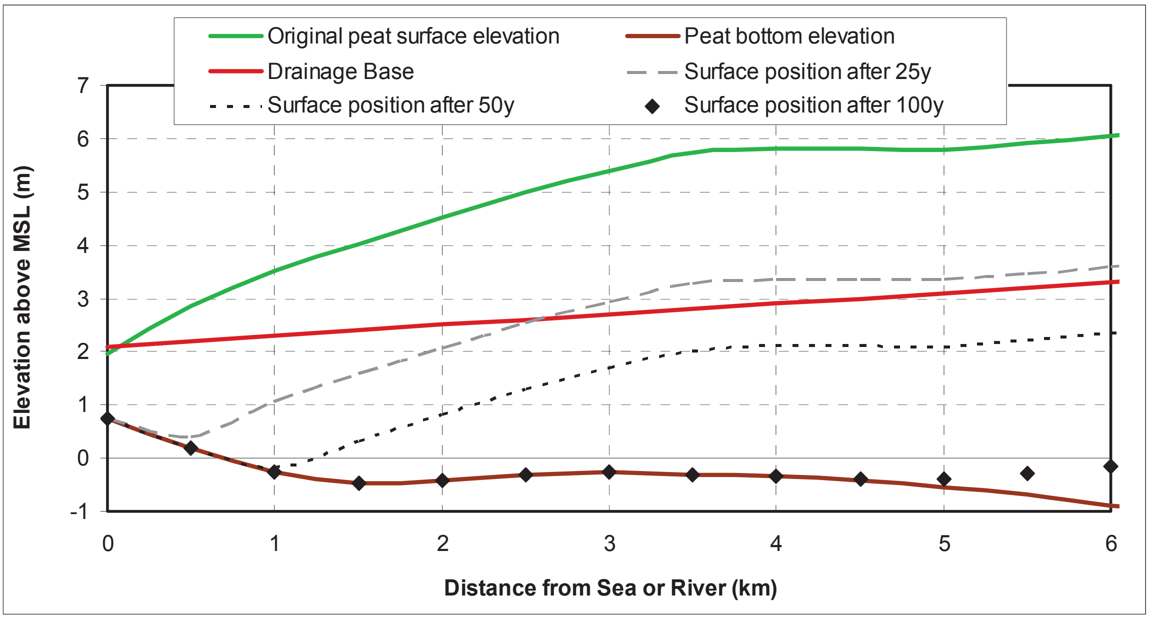


Figure 1 Average cross section over 42 profiles of peatland surface elevation and bottom depth in SE Asia. Projected surface elevations after drainage are also shown, relative to the Drainage Base that defines the start of drainage problems as the peat surface subsides.

Methods

As no accurate full coverage Digital Elevation Model is available for SE Asian lowlands at present, and the accuracy of peat depth maps is poor (leading to a general underestimation of peat depth), we have used measured cross sections of peat surface and peat depth to define the elevation of the peat surface and peat bottom above sea level. Most cross sections (over 80%) were in forested peatland with limited drainage, representing the situation before subsidence started. Of the 42 cross sections presently included in the analysis, 27 are from Malaysia (all from Sarawak) and 15 from Indonesia (equally from Sumatra and Kalimantan). Of these, 24 were taken from publications (notably Anderson 1964; Staub and Gastaldo, 2003), 14 from presentations and technical reports and 5 are from unpublished databases. The average length of cross sections included in the analysis is 9 km, varying from 2.5 to 24 kilometres; the total cross section length is 377 km.

To test at what point peatland drainability would be seriously affected by subsidence, we defined three threshold levels. Drainability is assumed to end in all cases when the peat surface is at MSL. In near-coastal tidal areas, drainability is affected when the surface is at High Tide level (estimated to be 1.5 m above MSL on average). Further away from the coast or rivers, drainability is affected when the surface approaches a Drainage Base which is defined by adding a conveyance gradient of 0.2 m km-1 to High Water Level for river dominated water levels, and to MSL for sea dominated water levels (Fig. 1). The conveyance gradient represents the water table gradient that should be maintained in canals to allow rainfall to be discharged from the land; the value of 0.2 m km-1 is a rule of thumb that is often applied in drainage system design and assessment (e.g. DID Sarawak, 2001).

To estimate the time it would take for subsidence to bring peat surface levels to the drainability thresholds, we applied an initial subsidence rate of 1.4 m in the first 5 years, followed by a constant rate of 5 cm y-1 in subsequent years (Hooijer et al., 2012). This calculation was done using the 42 individual original profiles.

Table 2 Statistics of peatland cross sections included in the analysis, as well as findings on drainability projections.

	Malaysia (Sarawak)	Indonesia (Kalimantan + Sumatra)	**Malaysia + Indonesia**
Number of cross sections available	27	15	**42**
Average length of cross sections, from river (km)	7.0	11.5	**9.0**
Average peat depth (m)			
Average peat depth (m)	6.2	7.5	**6.7**
Percentage peat depth > 3m	81%	88%	**83%**
Position of peat surface			
Position above MSL, 1 km from river (m)	3.8	3.1	**3.5**
Position above MSL, 5 km from river (m)	5.9	5.7	**5.8**
Position of peat bottom			
Percentage area where peat bottom below MSL	60	72	**63**
% peat bottom below MSL + Sea Level Rise[a]	67	78	**70**
% peat bottom below High Water Level[b]	83	98	**87**
% peat bottom below Drainage Base[c]	92	99	**94**
Trend in start of serious drainage problems (peat surface below Drainage Base[c])			
Percentage area affected after 25 years	46	49	**46**
% after 50 years	70	70	**69**
% after 100 years	83	92	**85**
Trend in end of gravity drainage (peat surface potentially at Mean Sea Level)			
Percentage area affected after 25 years	12	12	**12**
% after 50 years	32	28	**30**
% after 100 years	52	54	**52**

[a] *A value of 0.5 has been assumed for Sea Level Rise over 100 years (IPCC, 2007)*

[b] *High Water Level: High Tide Level (MSL + 1.5 m) near the Sea, and Bankful Flood Level along inland rivers (as defined by the position of levees in cross sections).*

[c] *The Drainage Base was defined by adding a conveyance gradient of 0.2 m/km to HWL for River dominated water levels, and to MSL for Sea dominated water levels.*

Results and Discussion

The analysis shows that the peat bottom is below MSL along 63% of the total length of all transects (more if the effect of sea level rise is added), below High Water Level along 87%, and below the Drainage Base along 94% (Table 2). This indicates that at least 63%, of drained peatlands in SE Asia may potentially become undrainable and unproductive. In reality, this number will be higher as drainability often ends when water levels approach the Drainage Base (DB).

According to these data, serious drainage problems will start within 25 years on 46% of drained peatland, and they will affect 69% of the land within 50 years. The onset of frequent inundation as the surface approaches MSL is expected to affect 12% of the land within 25 years and 30% within 50 years. After 100 years, 85% of drained peatland is projected to be below the Drainage Base and 52 % near MSL.

This analysis covers only a relatively small subsample of SE Asian peatlands. The individual cross sections are highly variable in shape, depending on location in the landscape and development history. More work will be needed to analyze a larger number of peatlands and increase the size and representativeness of the sample population.

It should be noted that the current analysis assumes that subsidence continues at a constant rate of 5 cm/y until the peat is depleted. It is suspected that subsidence rate actually slows down as the lowest few metres of the peat deposit are exposed, which can be more sapric in nature with higher bulk density and mineral content. Subsidence rates in such material tend to be lower than in fibric peat (Hooijer et al. 2011). Work on refining the analysis to account for this effect is ongoing. This will somewhat increase the time period before the peat surface approaches MSL. However it will have less effect on the time period before reaching DB, as at that point there is usually several metres of peat left and the peat at the surface would often still be expected to be fibric in nature (Fig. 1).

Figure 2 Frequently flooded oil palm plantation on a subsided peatland. Total subsidence is likely to have been over 2 metres since drainage in the early 1990s.

Conclusions

This tentative analysis confirms that SE Asia will be no exception to the global experience in drained peatlands. We find that serious drainability problems will start in a few decades after the onset of drainage and may lead to the end of agricultural production in between 30% and 69% of the coastal peatlands within 50 years. Eventually, most drained peatlands will inevitably be rendered unproductive. The higher subsidence rate in SE Asia implies that such problems will be evident much sooner than in cooler temperate climates. In fact, they are already beginning to be observed in some peatland areas which were drained in the early 1990s (Fig. 2), although increasing inundation frequency is so far rarely recognized as being caused by subsidence. Clearly, the decrease in drainability of coastal peatlands will become a major challenge for SE Asia. We propose that in land use planning and economic cost-benefit analyses, the benefits of increasing agricultural productivity on peatlands in the short term should be weighed against the inevitable increase in water management costs, and in many areas the medium-term loss of agricultural production and human livelihoods.

Further work will be required to reduce the uncertainty in these numbers. For a spatially explicit analysis, maps of elevation, peat depth and land cover need to be combined; such work is ongoing.

References

Anderson, J.A.R., 1963. The structure and development of the peat swamps of Sarawak and Brunei. The journal of tropical geography, 7-16.

Andriesse, J.P., 1988. Nature and management of tropical peat soils. FAO Soils Bulletin 59, Rome.

Camporese, M., Gambolati, G., Putti, M. and Teatini, P., 2006. Peatland subsidence in the Venice watershed. Chapter 23 in Peatlands: I.P. Martini, A. Martinez Cortizas and W. Chesworth (eds.). Evolution and Records of Environmental and Climate Changes, Elsevier, 529-550.

Deverel, S. J. and Leighton, D.A (2010). Historic, recent, and future subsidence, Sacramento-San Joaquin Delta, California, USA, San Francisco Estuary and Watershed Science 8(2), 23 pp.

DID Sarawak (2001). Water management guidelines for agricultural development in lowland peat swamps of Sarawak, Report of the Department of Irrigation and Drainage, Sarawak, Malaysia, 78 pp.

Hooijer, A., Page, S., Jauhiainen, J., Lee, W.A., Lu, X.X., Idris, A. and Anshari, G., 2011. Subsidence and carbon loss in drained tropical peatlands. Biogeosciences Discuss. 8, 8269–8302, doi:10.5194/bgd-8-8269-2011, in print in Biogesosciences.

Hooijer, A., Lee, W.A., Lu, X.X., Idris, A., Sugino, Jauhiainen, J. and Page, S., 2012. Subsidence as an accurate measure of carbon loss in drained peatlands in SE Asia. Extended abstract for the 14th International Peat Congress: Peatlands in Balance. International Peat Society.

Hutchinson, J. N., 1970. The record of peat wastage in the East Anglian fenlands at Holme Post, 1848-1978 AD. Journal of Ecology 68, 229-249.

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

Staub, J.R. and Gastaldo, R.A., 2003. Late Quaternary sedimentation and peat development in the Rajang River delta, Sarawak, East Malaysia. In: F. Hasan Sidi, D. Nummedal, P. Imbert, H. Darman and H.W. Posamentier (eds.). Tropical deltas of southeast Asia – sedimentology, stratigraphy, and petroleum geology. SEPM (Society for Sedimentary Geology) Special Publication Number 76, 71–87.

Stephens, J.C., 1956. Subsidence of organic soils in the Florida Everglades. Proceedings of the Soil Science Society of America 20, 77-80.

Stephens, J. C., Allen, L. H., and Chen, E., 1984. Organic soil subsidence, Geological Society of America, Reviews in Engineering Geology Volume VI, 107–122.

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

Fire detection and fire prediction group activities in JST-JICA project: current status and planning

Toshihisa Honma[1)]*, Kazuya Kazuya[2)], Aswin Usup[3)], Agus Hidayat[4)]

[1)] Centerfor Sustainability Science, Hokkaido University, Sapporo, Japan
[2)] JAXA, Tokyo, Japan
[3)] UNPAR2, Palangka Raya, Indonesia
[4)] LAPAN3, Jakarta, Indonesia

* E-mail address: honma@ist.hokudai.ac.jp

Through Fire Detection and Fire Prediction Group Activities in JST-JICA Project, the project target has been achieved as follows; (1) In the fire event with more than 1 km^2 coverage, 4 pilot villages can obtain fire information at an average of 13-16 hours. Fire spread prediction time for 2 km area from the pilot villages is about 4 hours when we apply simplified fire-extension model. (2) All record of 10 hotspot data (July 2009) and 2 current firing hotspot data (September 2012) detected by the improved algorithm were confirmed to be burnt or burning area by UAV photographs (100%). When we consider both omission and commission errors, hotspot detection accuracy is assumed to be able to achieve 80% level. (3) By using the simplified fire-extension model, 1 km square hotspot is approximated by either an inscribed circle with the radius 1/2 km or a circumscribed circle with the radius $\sqrt{2}/2$ km.When we consider the interval of satellite image acquisition, predicted fire spread coverage error becomes within 50% if the velocity of hotspot center is less than 2m/min.

Keywords: hotspot satellite data, UAV, fire detection & prediction, WSN.

Introduction

There are 3 numerical indicators in targets of Fire Detection and Fire Prediction Group Activities in JST-JICA Project. Namely, (1) in the fire event with more than 1 km^2 coverage, 3 pilot villages can obtain fire information within 16 hours, and moreover they can obtain information on fire spread prediction within 8 hours. (2) Fire detection accuracy can reach the level of more than 80%. (3) Rate between predicted fire spread coverage and real fire coverage can reach the level of more than 50%. In order to accomplish these targets, 8 project activities are introduced into research groups as shown in Figure 1. In addition, each status of 8 project activities is described in the section of project activities, issues remained are summarized in the discussion and conclusions are finally drawn.

Project Activities

1. Improvement ofthe hotspot algorithms

We have improvedthe precision of algorism proposed by the project by comparing it with other, 5 existing algorisms. MODIS (1 km^2 mesh) fire hot spot detection system was transferred to the server purchased and set up in LAPAN. Data has been accumulated every day since 20 May 2011.

In order to validate the satellite detection accuracy of hotspots data, aerial photography was taken by the electrically-powered unmanned aerial vehicle (UAV) equipped with optical camera and infrared camera. At this time, the hotspots map detected in July, 2009 was utilized because there were no fires occurred in study site during dry seasons in 2010-2011. All 10 hotspots in the 2009 map shown in Figure 2 were confirmed to be burnt area by UAV aerial photography in 2011 and 2012. In addition, two hotspots detected by satellite in 3rd September, 2012 were also confirmed to be real on-going fires by UAV aerial photography taken in 6th September, 2012. In a word, the improved hotspot detection algorithm could find the fire at 100% accuracy though the sample cases are limited. In addition, by UAV observation, it was confirmed that 15~20 % areas were burning inside the hotspots (1 km × 1 km) as shown in Figure 3. On the other hand, during the project, two UAV design were developed and tried. The improved UAV which can fly about 1 hour took the photography of the forest fire detected by the satellite for the first time in September 6, 2012.

2. Estimation of carbon emission by biomass burning among different ecotypes

The amount of carbon emission from biomass-burning was estimated based on the satellite data with a model established by FRP method and NDVI method, and the results was compared with those from NASA's existing database (GFED). For example, the amount of carbon emission originated from biomass in Kalimantan, from 2002 to 2010, was estimated as FRP: 2.5~24.2 TgC/yr, NDVI: 0.05~1.2 TgC/yr, GFED: 1.3~241.3 TgC/yr.

3. Transfer of in-situ fire information to each region

The software for the short message system (SMS) was selected and 4 pilot villages (Tarunajaya, Tumbang Nusa, Pilang and Djabiren) were selected for the installation of fire communication system. We procured the SMS system including both hardware and software in Indonesia and installed in Pekayon office, LAPAN. The fire information transmission system based on SMS was established, and introduced to the pilot villages. In addition, we developed the system that integrates useful forest fire information, for example, date of fire detection, the distance and the direction to occurred hotspots inside the distance 2 km from the center of villages as shown in Figure 4, the fire dangerous index determined by the soil moisture, and types of peat fires. The recipients of the fire communication system (SMS) are set to be village heads and leaders of fire-fighter teams.

4. Construction of prediction model of wild fire occurrence

A simulation model on forest fire spread in the large area (about 100 km × 100 km), taking into consideration the vegetation data, was developed and its validity was examined from viewpoint of both omission and commission errors in Figure 5. On the other hand, the time sequence of 1 km^2 hotspot data was examined and the fire occurrence process in time was clarified. As a result, the simplified fire-extension model was developed based on time-series hotspot data and the fire extension area was estimated as the movement distance of the hotspot center as shown in Figure 6. Namely, by using the simplified fire-extension model, 1 km square hotspot is approximated by either an inscribed circle with the radius 1/2 km or a circumscribed circle with the radius $\sqrt{2}/2$ km. Therefore, when we consider the interval of satellite image acquisition, predicted fire spread coverage error becomes within 50% if the velocity of hotspot center is less than 2 m/min.

Experiments of temperature increase by artificial fire were conducted, in which the temperature was measured by wireless sensor network (WSN) at 500 m away in distance and the applicability of WSN to fire prediction was confirmed. The new technical specification of the 500 wireless sensors that cover the area of 10 km × 10 km was elaborated.

5. Construction of model of water regime

A model was established to estimate the spatial distribution of soil moisture based on satellite data, and the validity of the model was verified by comparing the measurement data of ground water level with the model. By integrating the data from fixed point observation into the satellite data, the spatial distribution of soil moisture was presented with high precision for the first time in the world. The validity of the established water fluctuation/soil moisture estimation model was examined though the accumulation of data and fixed point measurement. In addition, the level of the peat fire index (PFI) was defined by the correlation of the ground water level with the number of fire occurrence and the fire dangerous index based on PFI was developed in Figure 7.

6. Make map of land cover/land use change

To understand the degradation of the forest from 2005 to 2010, maps of land cover and land use change were developed based on the LANDSAT satellite data. The time-series data of Normalized Difference Vegetation Index (NDVI) on typical areas was accumulated with the interval of 16 days, and the time of forest degradation by peat-forest fires or plantation as well as the cause of forest degradation was examined. Based on the time-series data from revised NDVI (EVI), the change over the years of forest conservation, forest degradation and the reforestation was examined with precision. We compared the satellite data of the vegetation change and degradation of land use due to peat-forest fires with the aerial photograph by UAV.

7. Establishment of spectral library (plant / soil) in investigation area

51 kinds of plants and soil and water spectrum were measured at around 70 observation points. The range of observation wave lengthis 350~2500 mm and the interval of data measurement is 0.1 second/spectrum. As to satellite data analysis, data with high precision has become available, and it has become possible to investigate the precision of estimating carbon emission from biomass due to peat-forest fires.

8. Validation ofestablished system

The several fire processes such as satellite hotspot detection, hotspot data analysis, fire information production and delivery, and UAV verificationis integrated as shown in Figure 8. The fire information can be obtained at an average of 13-16 hours. Average satellite detection time is 6-8 hours, hotspot data analysis time is 4 hours, fire information data production time is 1 hour and SMS data transmission time is 2-3 hours. The practical operation of fire detection and prediction based on the integrated systems and SMS is carried out (Figure 9 (a)-(d)). The usefulness of the information system for suppression of real fires by fire fighters was confirmed (Figure 9(e)-(f)). After suppression of fires, leaders of fire fighter teams reported to participants at meeting about the suppression activities based on fire information delivered through SMS, in which suppression starting and ending time, the type of fire, the fire burned area size and personal impression etc. are reported (Figure 9(g)). In addition, leader of UAV monitoring team explained the UAV flight performance and current moving images of real fires taken by UAV (Figure 9(h)). Stakeholders satisfied the reports from leaders and Q&A.

Discussion

Fire detection and fire prediction system was established and tried, so that target has been achieved at 80% completion level. However, there are issues still remained to be considered in the following.

We examine the validity and limitation of this proposed model, and discuss the points of improvement in this project. Firstly, in the simplified fire-extension model, we have to examine and establish the velocity of the movement of hotspot center determined by wind velocity, soil moisture and vegetation, and verify the precision of the simplified fire-extension model through the time-series hotspot data analysis and on-site inspection. In addition, we need to estimate the CO_2 emission due to fires based on the time-series hotspot data. Next, in order to validate the model established by FRP method and NDVI method, we have to estimate the amount of carbon emission from biomass by the observation on the ground of vegetation change due to forest fire, and the result is to be compared with that from this model.

In the fire communication systems, in order to send messages to stakeholders smoothly, we need to estimate traffic congestion time of SMS of real traffic in Indonesia. In addition, we have to discuss and coordinate about fire communication with local government authorities for its realization.

Finally, it is necessary to review the possibility of making accumulated data open for researchers, who will be able to share observation data among researchers even if the project is finished.

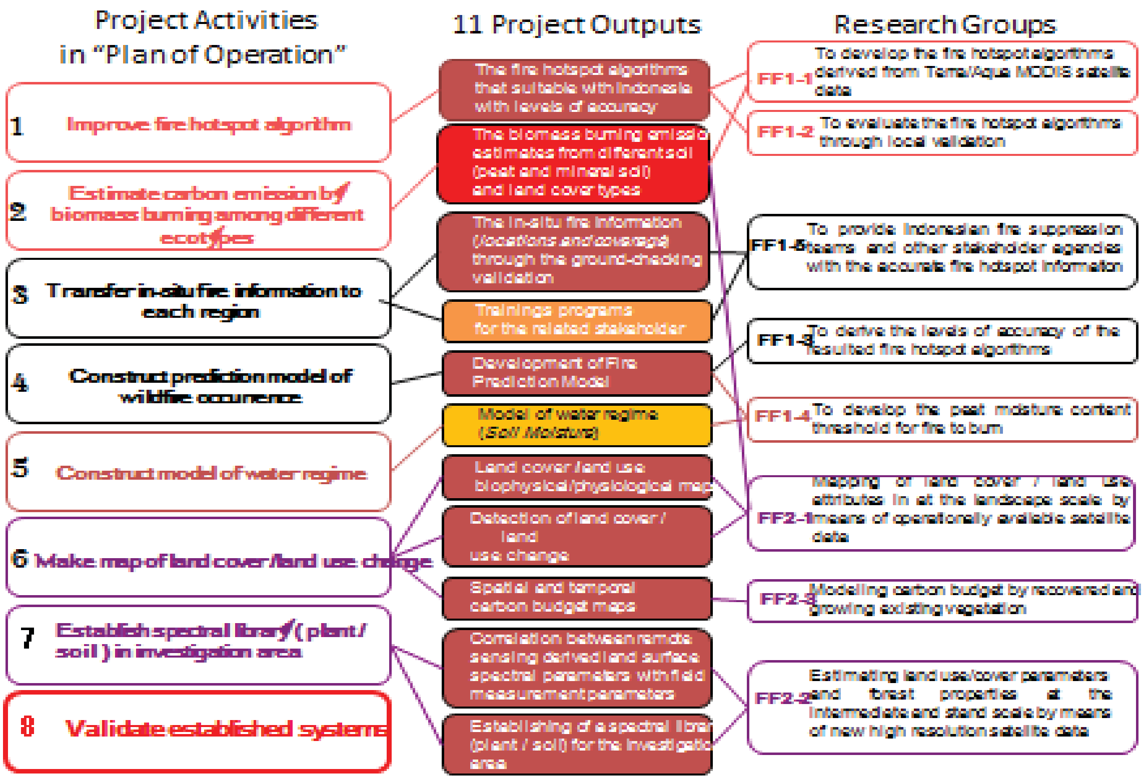


Figure 1.Relation between project activitiesand research groups

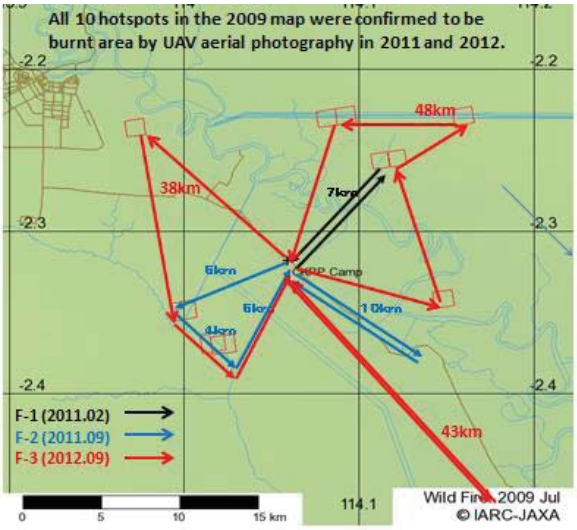


Figure 2. UAV flight routs for validation of hotspots satellite data

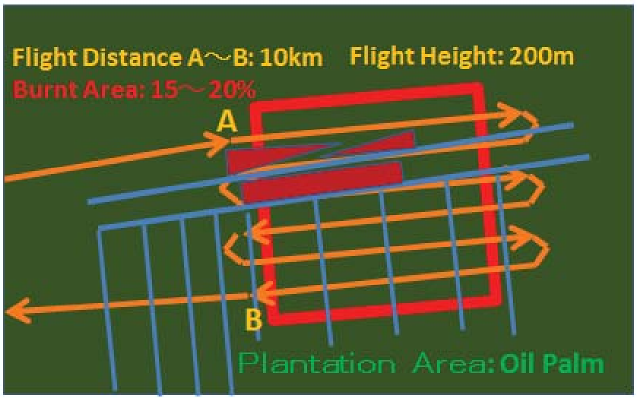


Figure 3. UAV flight rout inside a pixel for validation of hotspot satellite data

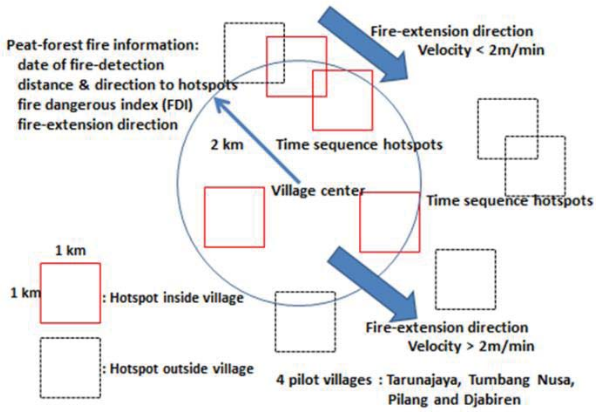


Figure 4. Hotspots inside the distance 2 km from the center of a village

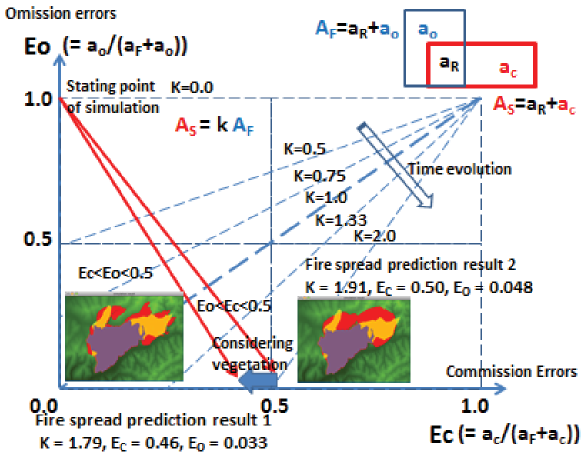


Figure 5. Simulation results of fire spread considering both omission and commission errors in the large area (100km × 100km)

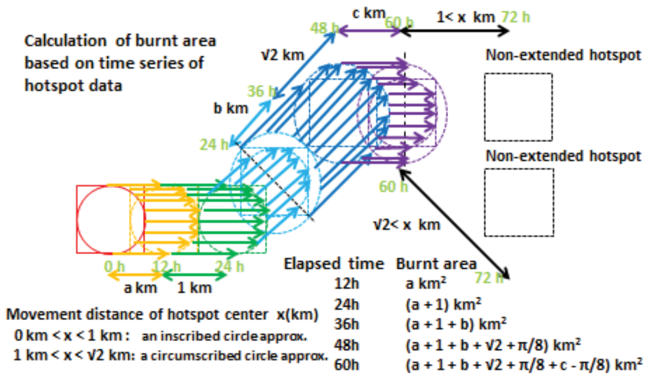


Figure 6. Simplified fire-extension model based on time-series hotspot data

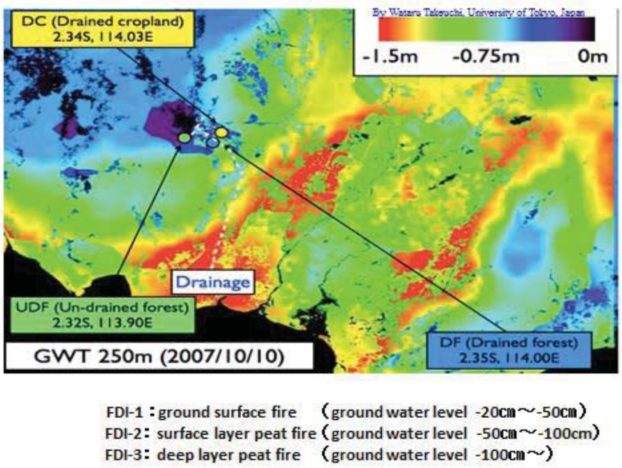


Figure 7. Two dimensional profile of fire dangerous index (FDI)

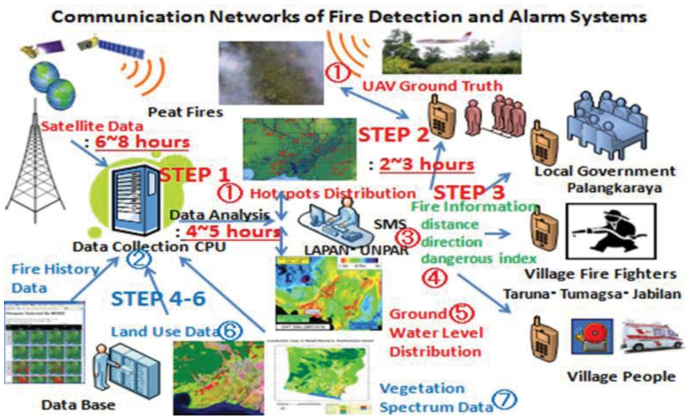


Figure 8. Fire communication networks

Figure 9. Workshop on practical fire operation

CO_2 flux observation by atmospheric temperature inversion trap method

G. Inoue[1)], M. Kawasaki[2)], M. Yamaguchi[3)], T. Asanuma[3)], K. Tsubokura[3)], A. Sakurai[4)], N. Matsuura[4)], A. Sasaki[4)], K. Kusin[5)], S.H. Limin[5)]

[1)] University of Tokyo,
[2)] Nagoya University
[3)] Meisei Electric Co.
[4)] Nippon-koei Co
[5)] University of Palangka Raya

We have proposed a cost-effective methodology for nocturnal CO2 emission measurement in the field, with which data processing is easier than the conventional eddy covariant and chamber methods.

Keywords: MRV, chamber method, inversion layer, temperature inversion

Introduction

The activity to supress the peat carbon loss, which is either peatland fire or microbial conversion to carbon dioxide in aerobic circumstance, should be easier than the suppression of fossil fuel use. In order to evaluate the amount of carbon reduction by the peatland conservation activity, the methodology to draw the business as usual base line, and the amount of emission reduction, MRV (Measurement, Reporting and Validation) by this activity should be developed.

The CO2 flux from flat and homogeneous land can be measured by micro- meteorological method called as the eddy covariant method. This is the measurement of vertical flux, from ground to the atmosphere, by covariance measurement of vertical wind velocity and CO2 concentration on a tower. This method is very accurate and operated continuously, but limited to homogeneous emission and not applicable to forest/peatland fire, which is a point source. The chamber method, to measure the concentration increase in a box covering a land surface, is a reliable method to measure the soil respiration, but it is very local. This method is not applicable to fire because the supply of oxygen is disturbed by the camber, even though the CO2 emission from underground fire may be measured.

In this report, the nocturnal inversion layer trap method to measure the soil flux including smouldering underground fire is proposed.

Results

In daytime, CO2 emitted on surface is mixed quickly by heat convection, but at night time CO2 remains near surface in the temperature inversion layer. We have developed the methodology to evaluate the accumulated CO2 in the temperature inversion layer from the data at two different heights, e.g., 1 and 5 m. The CO2 distribution change is assumed to be linear from the ground level to the inversion layer top, where the concentration is the same as the daytime before, or

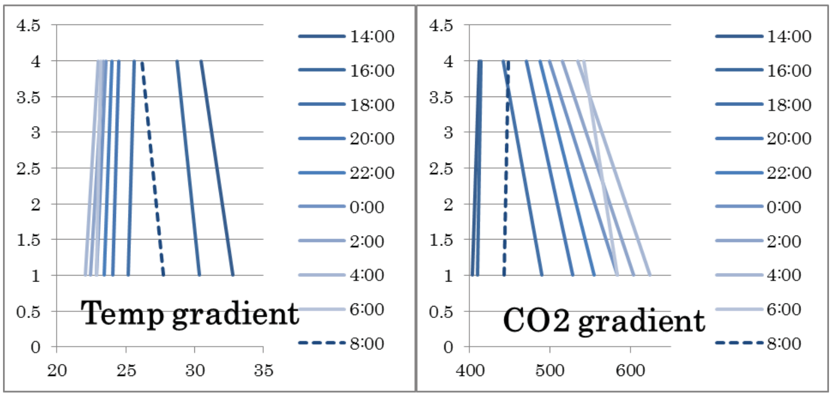


Fig. 1 Average temperature and CO2 concentration in calm days in February and March in 2013 at Palangkaraya. (left) Temperatures at 1 and 5 m height in daytime and at night time. Lines represent temperature gradients. Insets show measurement time. (right) corresponding CO2 concentrations at 1 and 5 m height.

the baseline concentration. Figure 1 (left panel) shows that in daytime temperature at the lower position (h = 1 m) is higher than at the higher position (h = 5 m). At night time this situation is revered from 17:30 until 5:30 of the next day, resulting in formation of the temperature inversion layer that disappears by sunrise at 6:00 as shown by the broken line. Figure 1 (right panel) shows the corresponding changes in CO2 concentration. The concentration at h = 1 m is a little lower in daytime because of photosynthesis by surface vegetation, but the surface concentration increases more than that at h = 5 m, and the extension of this line to a vertical line at 415 ppm is between 8-12 m, which is the inversion height. The area of this triangle, the vertical line at 415 ppm, the lines in Fig. 2 (right), and the horizontal line at 0 m, is the CO2 accumulated in the inversion trap, in ppm•m.

The amount of CO2 trapped is evaluated from the height distribution of CO2 from surface to the top of the inversion layer. The temperature inversion height varies by the radiative cooling speed controlled by cloud coverage, heat conductivity and capacity of soil, the wid speed etc. Temperature inversion height over wetland is as low as a few tens of meters because of thermal conductivity of soil is large over wet soil. The data of relatively strong inversion layers are selected based on the temperature inversion strength, that is, temperature gap $\Delta T = —0.5 \sim —1.5$ deg. where $\Delta T = T(\text{low position}) — T(\text{high position})$. Figure 2 shows the accumulated amounts of CO2 as a function of time. The slope of

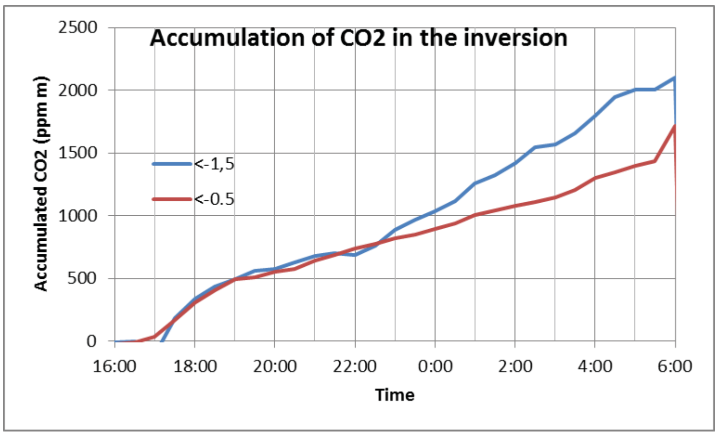
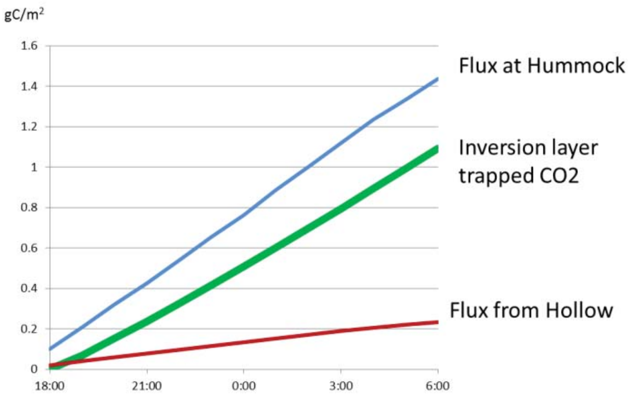


Fig. 2 Hourly averaged CO2 vs. temperature differences in calm days. At night time, the CO2 concentration at the lower position is higher by several tens ppm and the temperature inversion is in the range of -1.5 to -0.5 degrees. The CO2 concentration difference is close to zero before sunset.

these lines corresponds to the flux in ppm m/day or gC/m2/day. Since the amount of trapped CO2 depends on the temperature gap, the CO2 emission rates reported here are extraporated to large temperature gap to result in 1.06 gC/m2/day.

To obtaine a local CO2 flux from soil, the chamber method utilizes an increase in CO2 concentration in a chamber covering a particular area of 1×1 m or less. This measurement is suitable to know the relation between the flux and cotrolling factors, e.g., vegetation, temperature, soil water content, under-ground water level, nutrients and so on. We have also measured the CO2 flux with the chamber method in the same observation site with use of two chambers at hamock and hollow positions. Figure 3 shows comparison between the results from the chamber method and temperature inversion trap metholod. The amounts of CO2 trapped in the chambers after sunset are plotted, corresponding to the toatl flux



Accumulated CO2 taken from chamber data and inversion trap from sunset to sunrise are 1.06 and 0.23～1.43 gC/m^2, respectively.
This corresponds to the total flux in half a day.

in a half day. The values of the chamber method is about two times larger than those of inversion method. Invesion trapped amout was 1.06, which is between 0.23 and 1.43 gC/m2/day for hollow site and hamock site, respectively. The flux by the temperature inversion trap method is between the flux data of the hamock and hollow positions.

Discussion

The amount of carbon dioxide emission from dried peatlnad is similar in magnitude as that from forest/peatland fire. The microbial conversion from petland soil to CO2 is enhanced under the aerobic condition after drainage system construction. After trees are harvested or burned during the human activity converting from peatland to agriculture land, a large area is covered by either sparce trees or fern after fire and the CO2 emission is said significant.

The most reliable method to evaluate the CO2 flux is micro-metherological method called as the eddy covariance flux measurement that measures a flux in a 1×1 km area from the observation point. The estimated initial cost is high because of a tall tower, a sonic anemometer for vertical wind velosity measurement, a fast response CO2 sensors, a large-size data logger and a large power supply system. In addition, only trained scientists can analyse the data obtained from a limited number of observation sites.

From long term data at many places, we can develop a model to evaluate the emission using parameters, most of which can be obtained from satellite spectral imagin data set. However, the most important controlling factors in the tropical peatland is the distance between soil surface and underground water, which is determined by the underground water level and topological surface sturucture. However, it is difficlut to evalute them from remote sensing data of satellites.

Here we have proposed a cost-effective methodology for nocturnal CO_2 emission measurement, with which data processing is easier than the conventional methods.

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Effects of fires and drainage on dissolved organic carbon leaching through groundwater flow in tropical peat swamp forests

Siti Sundari[1)], Hiroyuki Yamada[2)], Takashi Hirano[2)], Kitso Kusin[3)], and Suwido Limin[3)]

[1)] Research Center for Biology, Indonesian Institute of Sciences (LIPI), Cibinong, Indonesia
[2)] Research Faculty of Agriculture, Hokkaido University, Sapporo, Japan
[3)] CIMTROP, University of Palangkaraya, Palangkaraya, Indonesia

[1)] E-mail address: ndariekologi@yahoo.com

The objectives of this study were to evaluate the effects of disturbances by fires and drainage on the DOC leaching through groundwater flow and assess DOC flux in tropical peatlands. To achieve the objectives, DOC fluxes were measured for more than one year in an undrained peat swamp forest (UF), a drained peat swamp forest (DF) and a drained burnt swamp forest (DB) in Central Kalimantan, Indonesia. Using such field data, DOC flux in tropical peatland ecosystems were assessed, and the effects of disturbances on them were investigated.

Keywords: Dissolved organic carbon, Drainage, Fires, Peat decomposition, Tropical peat swamp forests.

Introduction

Tropical peatlands, which are store up to 88.6 Pg of soil carbon, account for 15-19% of global peat carbon (Page et al., 2011). Peat degradation occurs most rapidly and extensively in Indonesia's peatlands because of fires, drainage and deforestation of swamp forests (Page et al., 2002; van der Werf et al., 2008; Couwenberg et al., 2010; Hooijer et al., 2010; Murdiyarso et al., 2010; Hergoualc'h and Verchot, 2011). On the one hand, tropical peatlands are one of the largest terrestrial carbon stores, but on the other hand, they export more organic carbon per unit area (i.e. Dissolved organic carbon (DOC)), than any other significant biogeographical land type in the world (Freeman et al., 2001; Page et al., 2002). The DOC export from peatlands occurs in two stages: (1) the production of DOC and (2) export with hydrological process. The DOC production in peatlands is usually measured from the increase in DOC concentration within peat pore water, though this increase (or decrease) represents the balance between release of DOC to the pore water and its consumption by biological, chemical, or physical processes. The DOC concentrations often become highest in periods under warm, dry conditions, when DOC has had time to accumulate. The DOC flux is important on watershed scale through river flow because in the flux of DOC will result in a significant regional redistribution of terrestrial carbon and DOC loss would be important for determining peatlands carbon balances (Moore et al., 1997; Billet et al., 2004). However, data concerning DOC leaching through groundwater flow in tropical peatlands were very limited, although DOC is not negligible and must be considered in the carbon balance of tropical peatland ecosystems.

Study site

This study was carried out at three tropical peat swamp forest sites in the upper catchment of the Sebangau River, near Palangkaraya, the capital city of Central Kalimantan province, Indonesia. One site was an undrained forest (UF) in Setia Alam area. The others were drained forest (DF) and drained burnt site (DB) in Kalampangan area. UF and DF had been logged until the late 1990's, and DB was burnt in 1997, 2002 and 2009.

Methods

DOC flux was calculated using water flux and DOC concentration. In order to obtain the water flux, a tank model was adopted (Sugawara et al., 1983; Umeda and Inoue, 1984). The single tank model was based on a premise that water flux has been increased in proportion to water content in the tank. To calculate both of surface water flux and groundwater flux, groundwater level and evapotranspiration data were used. Groundwater level was measured continually every 10 minutes at three wells in each site and evapotranspiration was measured on towers at each site. Groundwater samples were collected every two weeks from July 2010 to January 2012 at three wells in each site and analyzed for groundwater (GW) DOC concentration using Total Organic Carbon (TOC) analyzer. In addition, surface water (SW) samples were collected on February 7, 2012 at three points near the wells in the UF and DB sites, respectively, and analyzed for surface water (SW) DOC concentration. In each site, groundwater (GW) DOC flux was obtained by multiplying GW DOC concentration by groundwater flux. In the UF and DB sites, surface water (SW) DOC flux was obtained by multiplying SW DOC concentration by surface water flux.

Results

The highest GWL was measured at the UF site and the lowest GWL was at the DF site. The GWL was higher at the DB site than at the DF site. The seasonal variations in GWL at the DF site was similar to that at the DB site, but a little bit different from that at the UF site, with the maximum in October 2010 and minimum in August 2011, respectively, at each site. The GWL-changing was corresponding with precipitation. As well as GWL, the maximum and minimum values of daily precipitation were also recorded in October 2010 and August 2011, respectively, at each site (Fig. 1). Monthly precipitation from July 2010 to December 2011 was more than 100 mm, except in June and August 2011. For that reason, the period of June and August was defined as the dry season in 2011.

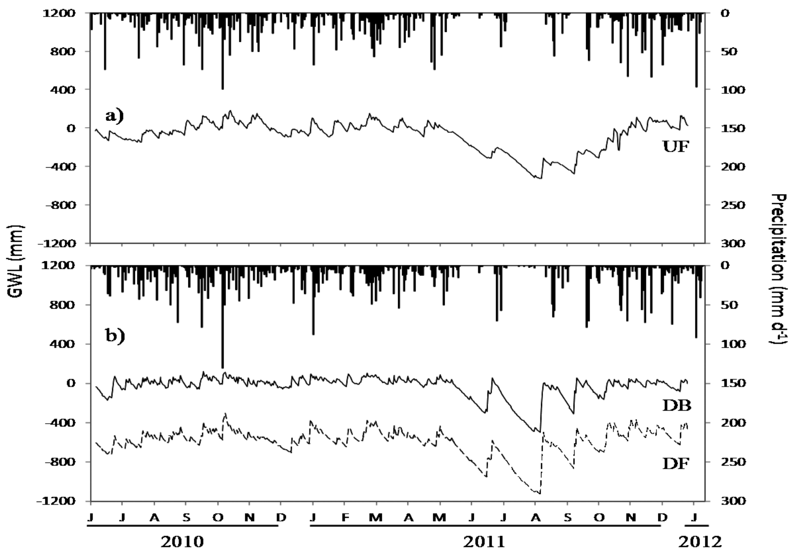

Fig. 1 Seasonal variations in daily mean groundwater level (GWL) and precipitation.

The highest DOC concentration was measured at the DF site on January 2012 and the lowest was at the DB site on September 2010. The DOC concentration was higher at the UF site than that at the DB site on each sampling date, except in August and October 2010. The DOC concentrations ranged from 6.4 to 54 mg L-1, from 13.4 to 78.6 mg L-1 and from 10.8 to 38.5 mg L-1 at the UF, DF and DB sites, respectively (Fig. 2).

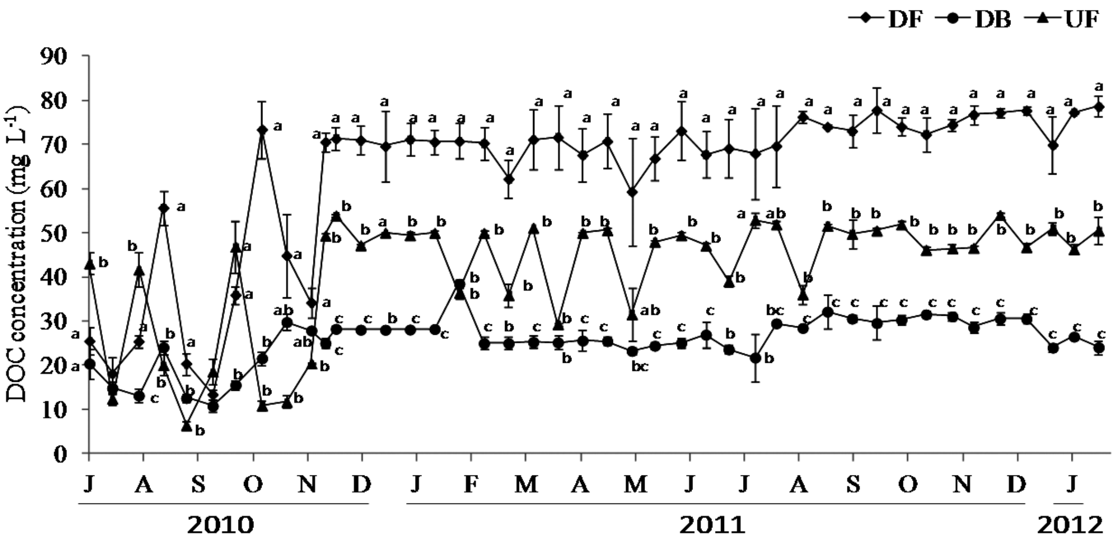

Fig. 2 Seasonal variations in DOC concentrations of groundwater at the UF, DF and DB sites from July 2010 to January 2012.Vertical bar denotes standard error (SE) of three wells on each sampling date at each site. Significant differences among the sites on each sampling date are denoted by different letters (Scheffe's test, $p < 0.05$).

Water budget error was obtained by subtracting precipitation (P) by evapotranspiration (ET), groundwater flux (G) and surface water flux (S).

Table 1 Water balance at each site

Site	Precipitation (mm)	Evapotranspiration (mm)	Surface water flux (mm)	Groundwater flux (mm)	Error (mm)
From June to December 2010 (189 days)					
UF	1680	970	300	484	-74
DF	1791	760	0	1084	-52
DB	1791	813	723	308	-53
From January to December 2011 (365 days)					
UF	2831	1758	326	721	25
DF	3021	1538	0	1324	159
DB	3021	1566	970	508	-22

Water budget was indicated as: Error = P – ET – G – S

The groundwater (GW) flux showed a small seasonal variation from July 2010 to December 2011 at the UF and DB sites. However, the GW flux showed a large seasonal variation from July 2010 to December 2011 at the DF site. The monthly GW flux ranged from 27.12 to 88.35 mm month-1, respectively, in October and March 2011 at the UF site, from -18 to 268.06 mm month-1, respectively, in August 2011 and November 2010 at the DF site, and from 21.12 to 56.29 mm month-1, respectively, in August and March 2011 at the DB site. As well as GW DOC concentration, the highest GW flux was estimated at the DF site (Fig. 3a).

The surface water (SW) flux showed a large seasonal variation from July 2010 to December 2011 at the UF and DB sites, except from July to October 2011. The maximum and minimum values of monthly SW fluxes were 149 mm month-1 in March 2011 and 0.64 mm month-1 in July 2010, respectively, at the UF site. They were 234 mm month-1 in November 2010 and 13 mm month-1 in June 2011, respectively, at the DB site. There was no SW flux in August 2010 and from July to November 2011 at the UF site and from July to October 2011 at the DB site. The monthly SW flux was higher at the DB site than that at the UF site (Fig. 3b).

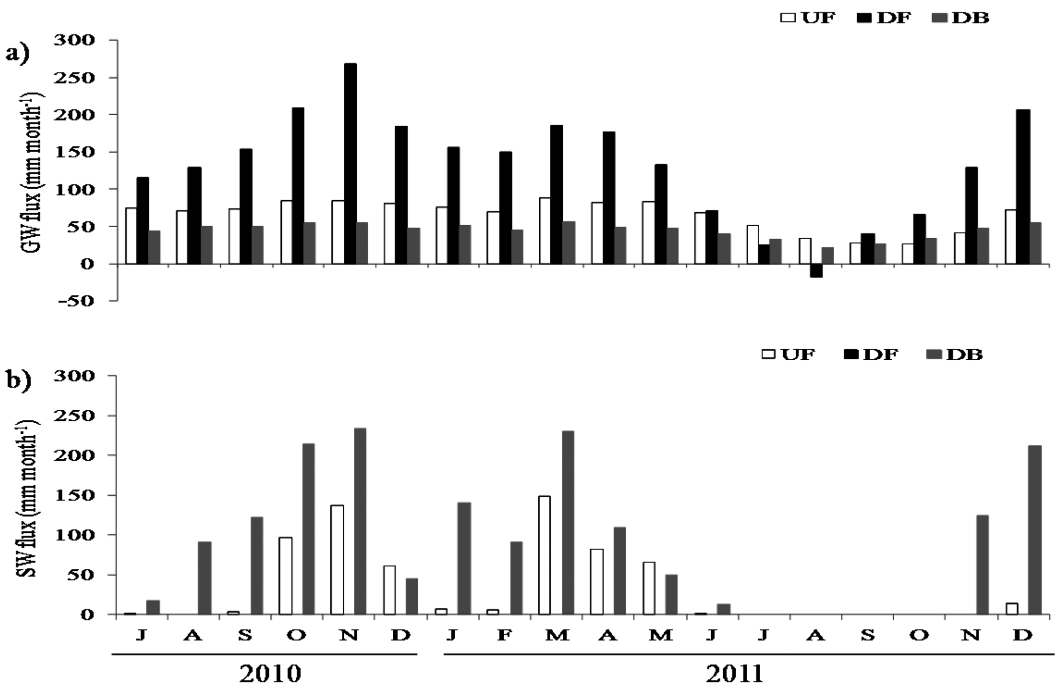

Fig. 3 a) Monthly groundwater (GW) flux at the UF, DF and DB sites; b) Monthly surface water (SW) flux at the UF and DB sites, with no SW flux at the DF site.

Seasonal variation in groundwater (GW) DOC flux was similar to that in GW flux at each site. The GW DOC flux showed a small seasonal variation from July 2010 to December 2011 at the UF and DB site. However, the GW DOC flux showed a large seasonal variation from July to December 2011 at the DF site. The monthly GW DOC flux ranged (mean ± SD) from 1.21 ± 0.16 to 4 ± 0.02 gC m-2 month-1, respectively, in October and December 2010 at the UF site, from -1.32 ± 0.03 to 16.39 ± 0.51 gC m-2 month-1, respectively, in August 2011 and November 2010 at the DF site, and from 0.63 ± 0.05 to 1.66 ± 0.03 gC m-2 month-1, respectively, in August and January 2011 at the DB site. As well as GW DOC concentration and GW flux, the highest GW DOC flux occurred at the DF site (Fig. 4a).

The surface water (SW) DOC flux showed a large seasonal variation following SW flux from July 2010 to June 2011 at the UF and DB sites, except from July to October 2011. The monthly SW DOC flux was higher at the DB site than that at the UF site. The maximum and minimum values of monthly SW DOC fluxes were 13.06 gC m-2 month-1 in March 2010 and 0.33 gC m-2 month-1 in June 2011, respectively, at the DB site. There was no SW DOC flux from July to October 2011 at the DB site. In the UF site, the maximum and minimum values of monthly SW DOC fluxes were 6.98 gC m-2 month-1 in March 2011 and 0.03 gC m-2 month-1 in July 2010, respectively. There was no SW DOC flux in August 2010 and from July to November 2011 in the UF site (Fig. 4b).

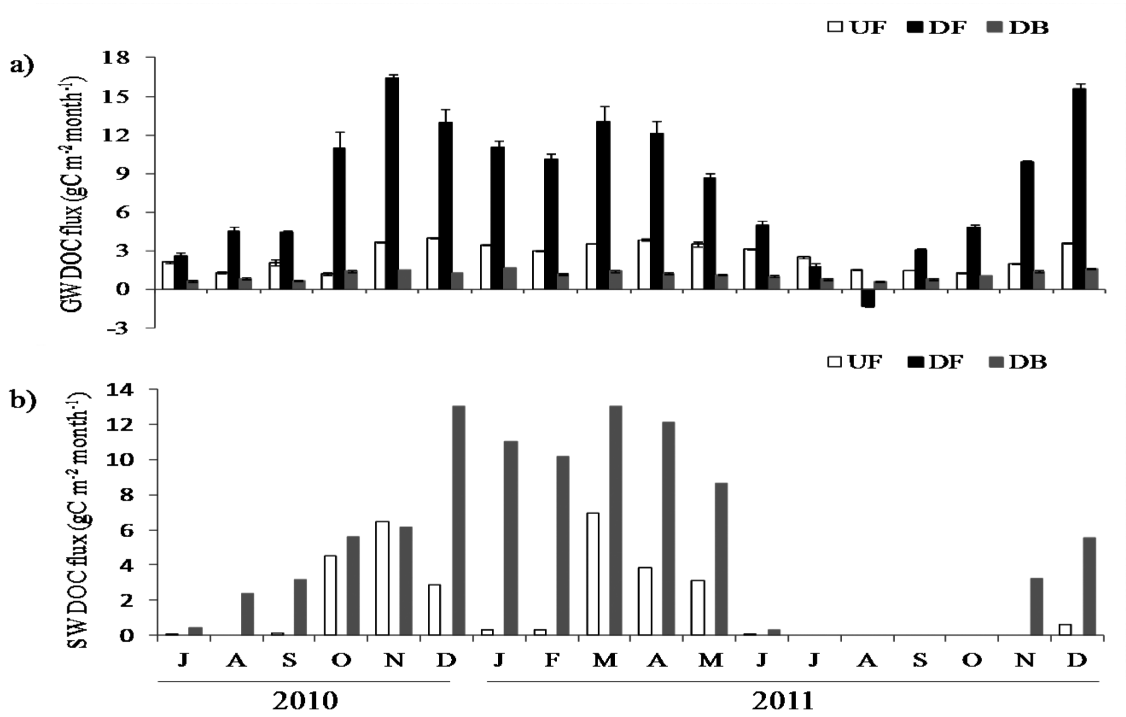

Fig. 4 a) Mean monthly groundwater (GW) DOC flux of three wells at the UF, DF and DB sites, vertical bar denotes standard error (SE) of three wells on each month at each site; b) Monthly surface water (SW) DOC flux at the UF and DB sites, with no SW DOC flux at the DF site.

Total DOC flux was obtained by the summation of groundwater DOC flux and surface water DOC flux. The cumulative total DOC flux for six months in 2010 (from July to December 2010) was estimated at 28, 52 and 37 gC m-2, respectively, at the UF, DF and DB sites. The annual total DOC flux in 2011 (from January to December 2011) was estimated at 48, 94 and 78 gC m-2 y-1, respectively, at the UF, DF and DB sites. The largest cumulative total DOC flux for six months in 2010 and annual total DOC flux in 2011 occurred at the DF site and the smallest occurred at the UF site. They were larger at the DB site than at the UF site.

Discussion

Generally, DOC concentrations of groundwater were higher in the dry season than in the wet season at each site, although groundwater flux and DOC flux were higher in the wet season than in the dry season. Moore et al. (1989) showed that DOC was more produced with increasing temperature in the dry season because the production of DOC was primarily controlled by biological process. Furthermore, the discrepancy in DOC concentration between dry and wet seasons was probably attributable to precipitation. The DOC concentration in the wet season was affected by the high precipitation. There would be considerable leaching and dilution of DOC during high precipitation events. In the wet season, because more water passed through the forest floor and the contact time between the soil and soil solution was short, DOC concentration was lower. However, low soil water content and longer contact time between the soil and soil solution in the dry season would lead to higher DOC concentration. However, the flux of DOC during the wet season was high because of high discharge, even though the DOC concentrations were low. The DOC flux was directly related to the amount of water flowing through peat soils and so would increase in the wet season.

The DF and DB sites had been drained in the late 1990s for Mega Rice Project and the DB site was burnt three times after drainage. Fires drastically change the biological and physical properties of the land surfaces, affecting many biological and hydrological processes (Bayley and Schinder, 1991), whereas drainage to lower GWL potentially enhances peat decomposition steadily (Furukawa et al., 2005; Melling et al., 2005). In the DB site, DOC concentration was the lowest among the sites because of the reduction of organic matter decomposition in burned soil and DOC dilution. The reduction of soil organic matter would decrease the production of DOC and much water on a relatively flat peat at the DB site would increase the dilution of DOC. Shibata et al. (2003) indicated that the fires significantly decreased the DOC concentration about one month after the fire in spruce forest because the production of black carbon (charcoal) from the burned soil would affect the DOC dynamics on the land surface and it is likely that the black carbon from the burned soil adsorbed DOC had contributed to the decrease of the DOC concentration in the leached water from the soil layer. However, in the DF site, DOC concentration was the highest among the sites because GWL-lowering by drainage could directly enhance the production of DOC by increasing the aerobic zone. The DOC was produced during the decomposition of organic matter in soil and could also be used as a substrate for microbial activity which involves the further production of DOC which resulted in higher DOC production (Bengtson and Bengtsson, 2007). As well as DOC concentration, the highest groundwater flux and DOC flux occurred at the DF site, suggesting a drainage effect.

Total DOC flux in 2011 at the UF, DF and DB sites, respectively, 48, 94 and 78 gC m-2 y-1 was not so different from annual DOC flux (83 gC m-2 y-1; Moore et al., 2011) of the previous study on DOC flux in this area (Sebangau catchment) because annual DOC flux in Sebangau catchment was an average value of total DOC flux from the area surrounding Sebangau catchment, including UF, DF and DB sites, villages, etc. The difference between both studies was the method and period of sampling. In this study, annual DOC flux of groundwater at each site was obtained based on continual DOC sampling every two weeks during the dry and wet seasons in 2011. However, Moore et al. (2011) obtained the annual DOC flux of the entire Sebangau catchment based on two sampling over the course of year, in September 2008 and March 2009.

Conclusions

The concentrations of DOC were higher in the dry season than in the wet season. This seasonal variation was probably caused by enhanced peat decomposition under drought conditions. Groundwater level-lowering by drainage enhanced peat decomposition that resulted in high production of DOC and much water was out of the peatlands caused by drainage, increased groundwater flux. Therefore, the highest DOC concentration, groundwater flux and DOC flux were estimated at the drained forest, suggests that the effect of drainage was larger than that of fires on the DOC leaching through groundwater flow in tropical peat swamp forests.

Acknowledgement

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References

Bayley, S.E. and Schindler, D. E. (1991). The role of fire in determining stream water chemistry in northern coniferous forests. In ecosystem experiments, Scope 45, Ed. HA Mooney, E Medina, DW Schindler, Ed Schulze, and BH Walker, John Wiley and Sons, Chichester. pp 141-165.

Billett, M.F., Palmer, S. M., Hope, D., Deacon, C., Storeton-West, R., Hargreaves, K. J., Flechard, C. and Fowler, D. (2004). Linking land-atmosphere-stream carbon fluxes in a lowland peatland system. Global Biogeochemical Cycles, 18, 1-12.

Couwenberg, J., Dommain, R. and Joosten, H. (2010). Greenhouse gas fluxes from tropical peatlands in south-east Asia. Global Change Biology,16, 1715-1732.

Freeman, C., C. D. Evans, D.T. Montelth, B. Reynolds, and N. Fenner, (2001). Export of organic carbon from peat soil. Nature, 412, 785.

Furukawa, Y., Inubushi, K., Ali, M., Itang A. M. and Tsuruta, H. (2005). Effect of changing groundwater levels caused by land-use changes on greenhouse gas fluxes from tropical peatlands. Nutr.Cycl.Agroecosys., 71, 73-91.

Hergoualc'h, K. and Verchot, L. V. (2011). Stocks and fluxes of carbon associated with land use change in Southeast Asian tropical peatlands: A review. Global Biogeochem. Cy.,25, doi: 10.1029/2009GB003718.

Hooijer, A., Page, S., Canadell, J. G., Silvus, M., Kwadijl, J., Wosten, H. and Jauhiainen, J. (2010). Current and future CO2 emissions from drained peatlands in Southeast Asia. Biogeosciences,7, 1505-1514.

Melling, L., Hatano, R. and Goh, K. J. (2005). Soil CO2 flux from three ecosystems in tropical peatland of Sarawak, Malaysia. Tellus,57B, 1-11.

Moore, S., Gauci, V., Evans, C.D. and Page, S.E. (2011). Fluvial organic carbon losses from a Bornean blackwater river. Biogeoscience, 8, 901-909.

Moore, T. R. and Clarkson, R. J. (1989). Dynamic of dissolved organic carbon in forested and disturbed catchments, Westland, New Zealand, 2. Larry River. Water Resource Research, 25, 1331-1339.

Moore, T.A. and Shearer, J. C. (1997). Evidence for Aerobic Degradation of Palangka Raya Peat and Implications for its Sustainability. In: J.O. Rieley& S.E Page (eds) Tropical Peatlands, Samara Publishing Limited, Cardigan. pp 55-72.

Murdiyarso, D., Hergoualc'h, K. and Verchot, L. V. (2010). Opportunities for reducing greenhouse gas emissions in tropical peatlands. P. Natl. Acad. Sci. USA,107, 19655-19660.

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

Page, S. E., Rieley, J. O. and Banks, C. J. (2011). Global and rangeal importance of the tropical peatland carbon pool. Global Change Biol.,17, 798-818.

Shibata, H., Petrone, C. K., Hinzman, L. D. and Boone, R. D. (2003). Effect of fire on dissolved organic carbon and inorganic solutes in spruce forest in the permafrost range of interior Alaska. Soil Sci. Plant Nutr., 49, 25-29.

Sugawara, M., Watanabe, I., Ozaki, E. and Katsuyame, Y. (1983). Reference manual for the tank model. National Research Center for Disaster Prevention, Tokyo.

Umeda, Y. and Inoue, T. (1984). The influence of evapotranspiration on the groundwater table in peatlands. Journal of the Faculty of Agriculture, Hokkaido University, 62 (2), 167-181.

van der Werf, G. R., Dempewolf, J., Trigg, S. N., Randerson, J. T., Kasibhatla, P. S., Gigliog, L., Murdiyarso, D., Peters, W., Morton, D. C., Collatz. G. J., Dolman, A., J. and Defries, R. S. (2008). Climate regulation of fire emissions and deforestation in equatorial Asia. P. Natl. Acad. Sci. USA,105, 20350-20355.

The scenario of carbon management by water management, fire fighting and forest recovery in tropical peatland

Hidenori Takahashi[1)], Adi Jaya[2)] and Suwido H. Limin[2)]

[1)] CENSUS, Hokkaido University, N9 W8, Kita-ku, Sapporo,
Hokkaido 060-0809, JAPAN, nana77hihc@ybb.ne.jp
[2)] CIMTROP, University of Palangka Raya, Kampus UNPAR, Palangka Raya,
Central Kalimantan, 73111 Indonesia

Summary

Peat surface moisture was significantly higher in the forest comparing that of grass land. This high moisture in the forest will be important for prevent easy igniting of surface peat. To control the carbon emission by peat fire and microbiological decomposition from tropical peatlands, the efficiencies of rewetting peatlands by rising groundwater level, controlling peat fire by firefighting, recovering forest were evaluated with some outcomes of the JST-JICA SATREPS project "Wild Fire and Carbon Management in Peat-Forest in Indonesia". Carbon emission by peat fire after the rising groundwater level with dam construction is estimated to be 76% of that before dam construction. The extinguish rate by fire fighting is directly affect on the decreasing rate of carbon emission from peatlands. Using relationship between the net ecosystem CO2 exchange (NEE) and groundwater level (Hirano, et al., 2012), the amount of carbon emission from the un-drained forest was estimated to be decreased to 27% by rising the annual mean groundwater level from 0.2 m to 0.1 m.

Introduction

Soil moistures of surface layer in tropical peatland are different with the canopy density of trees at the sites. And the moisture has a relationship with the occurrence of peat fire (Adi Jaya et al., 2011). The one dimensional tank models were applied to estimate the difference of surface peat moisture in open grass land and dense forest. The surface peat moisture in open grass land has been dried by evapotranspiration from surface layer in three month after the last rain fall. But the surface peat moisture in the forest was not so dry (Takahashi, et al., 2013). The higher moister content of surface peat layer in the forest means that forest recovery on peatland is one of keys for pear fire prevention.

Rewetting of peatland by rising groundwater level is the most important and basic method for peat fire prevention (Takahashi et al., 2011). The most of peat fire is caused by human carelessness. The extinction of fire in early stage is the most important to prevent the surface fire spread to peat fire.

The outline of scenario of carbon management is mentioned and the reduction of carbon emission from peatlands was roughly estimated in this paper.

***Key words**: groundwater level, canopy density, peat moisture, carbon emission.*

1. The effect of forest canopy on prevention of peat fire

1.1. Peat moisture in the fields

a. Study sites for peat moisture measurement

Two sites different in surface cover and land use were set for measurement of peat surface moisture in the tropical peatland of Central Kalimantan. The first one is a peat swamp forest (NF) without large effect of canal in the Sebangau Nature Laboratory. The second one is the reforested area small tree cover after peat fire (Fig. 1).

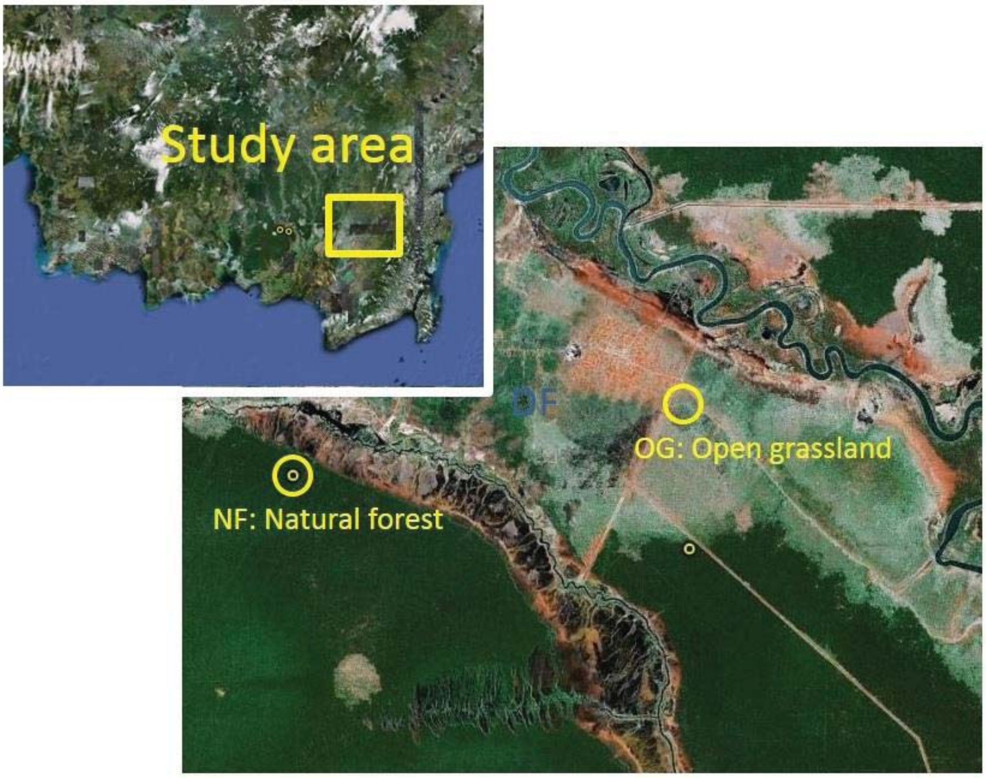


Fig. 1. Location of study sites in Central Kalimantan

b. Measurement of peat moisture

Measurement of peat moisture was carried out using DL6 with Theta Probe (ML2x) sensor. The sensor was barried in the peat soil layer with 5 cm in depth. The data was recorded with 1 hour interval. The grondwater level logger, DL/N70 STS, was set at the same locations. The measurements was conducted from the first June in 2011 to 13 August 2013 for more than 2 years. The results of the measurement were shown in Figure 2.

c. Annual change of thesurface peatmoisture in the fields

Moisture of surface peat layer in the forest is clearly higher than that in the grassland during dry season in 2011 and 2012 (Fig.1). The dry seasons in both years were not so longer than that in 2009 then the moisture of the surface peat in grassland was not lower than 0.4. But the surface peat moisture in the open grassland OG was decreased very soon after rainfall. On the other hand, it in the forest, NF, was decreased slowly. The difference of the decreasing speed of peat moisture in both sites was caused by the difference of strength of solar radiation on the ground surfaces. From this result, we can conclude that the forest canopy has an important role to keep the surface peat in wetter condition.

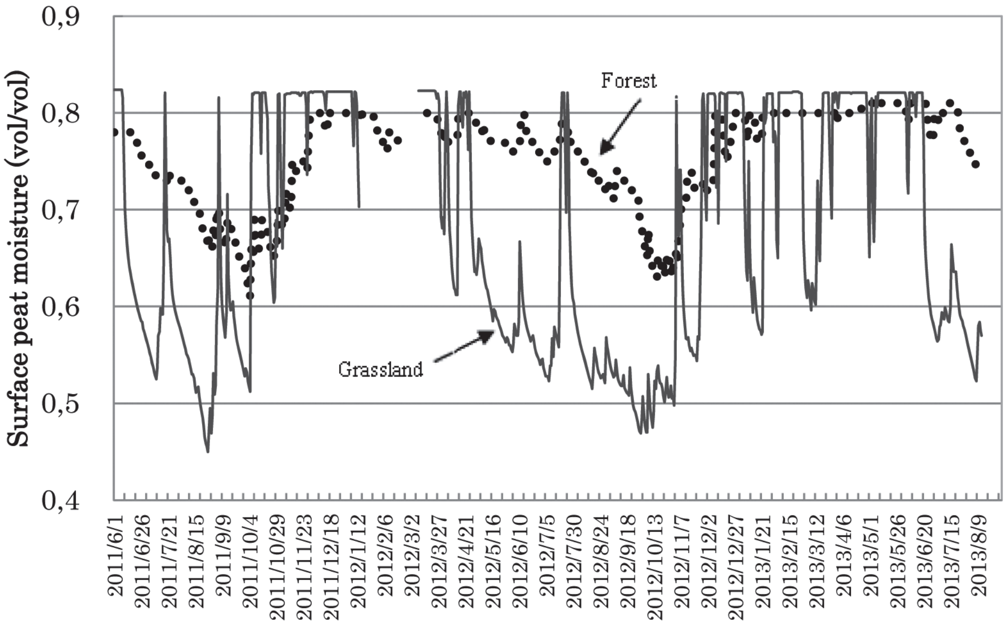


Fig. 2. Annual changes of the moisture of surface peat layers in a grass land and forest

1.2. Peat moisture and ignition

The probability of ignition on peat shown in Fig. 3 was reported by Babrauskas (2003). The Fig. 3 was rewritten with selecting the data of the upper sphagnum and lower sphagnum, and adding the axes of the moisture calculated by volumetric base.

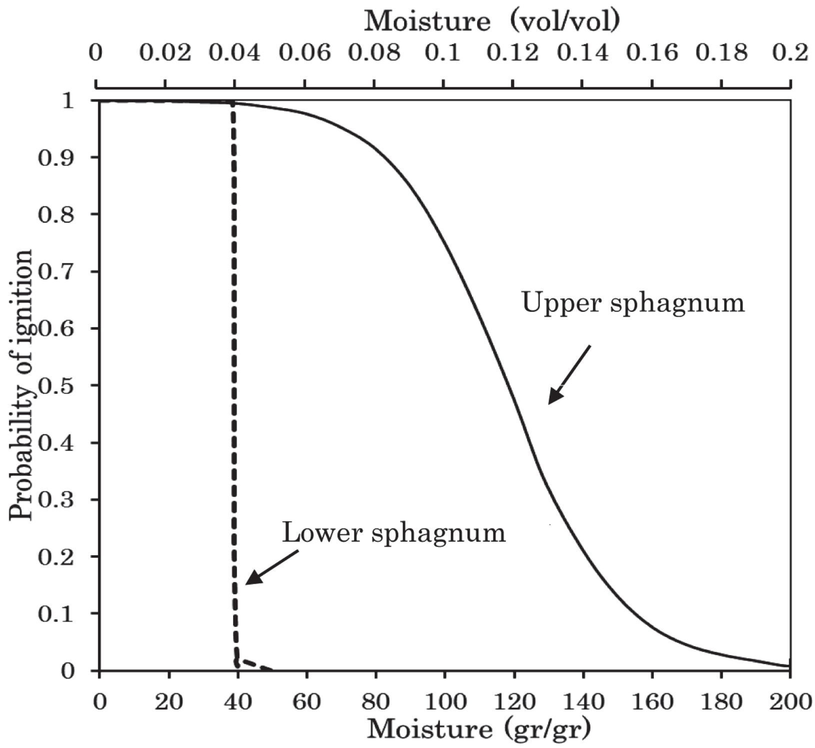


Fig.3 Probability of ignition on peat moss as a function of moisture (after Babrauskas, 2003, with redrawing by author)

The dry bulk density of tropical peat in the basin and dome area is 98.4 ± 22.3 kg m^{-3}(Shimada et al, 2001). The dry bulk density of 100 kg m^{-3} was used for convert the peat moisture from the gravimetric density to volumetric/bulk density in Fig. 3.

Jaya, A. et al. (2012) pointed out by analyzing the relationship between number of fire spot observed by MODIS and peat moisture in a forest that the critical moisture of peat for ignition was around 0.15 in volumetric moisture. The probability of ignition of the upper sphagnum also increases at around 0.15 in volumetric moisture in Fig.3.

From the moisture behaviors of surface peat layers in the forest and the open grassland, the forest canopy is very important for keeping the surface peat in wet and preventing the surface peat lay is ignited.

2. Controls of carbon emission by rewetting and fire management

2.1 The rising of groundwater level by construction of dams in the canal

Ishii et al. (2012) conducted very precise measurements of water level in the canal, groundwater level in the peat dome in the north of block C, Mega Rice Project area. The effect of dam construction on the groundwater level was calculated by using MODFLOW model and shown in the figures (Fig. 4).

The groundwater level near the center of the target area, where was the top of peat dome, rose around 1 m at near the canal and 0.2 m at 400 m far from the canal after dam construction.

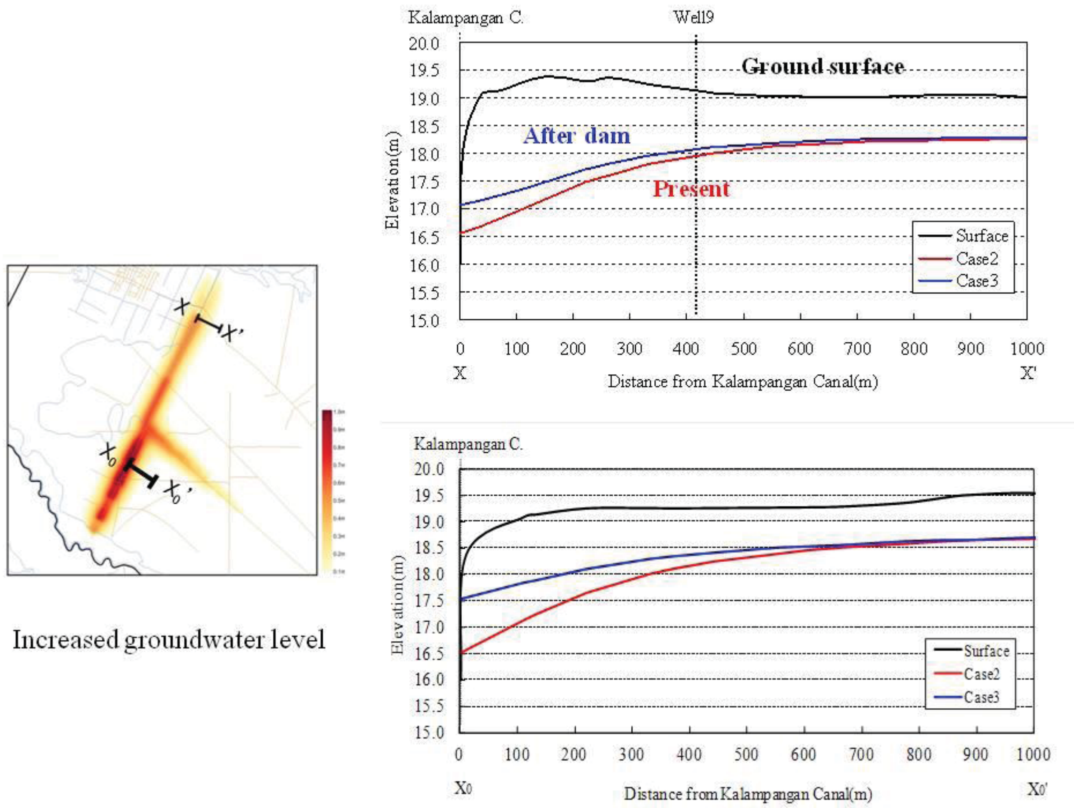


Fig. 3. Change of groundwater level after the construction of dams in the canal (after Ishii, 2012)

The effect of rising groundwater level on the carbon emission was evaluated using the relationship between the annual lowest groundwater level and the amount of carbon emission from MRP area shown in Fig. 4.

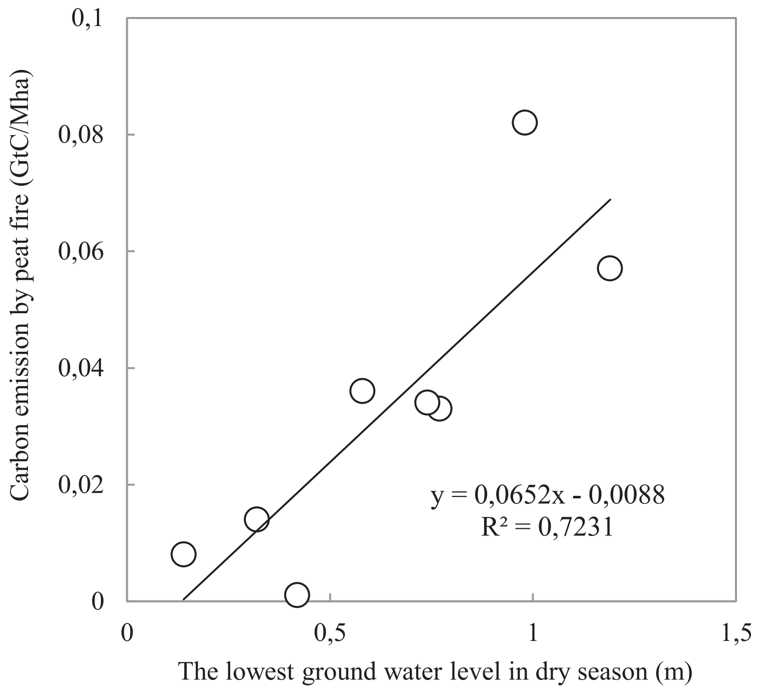


Fig. 4 The amount of carbon emission by peat/forest fire relating to the annual lowest groundwater level in a peat swamp forest in Central Kalimantan. Groundwater level was measured at the site in the Sebangau National Park, named Plot-1b and located 2°19'15.80"S, 113°54'4.10"E in coordinate. The amount of carbon emission was estimated using the number of fire spot in the Mega Rice Project area by Dr. Indra Putra.

The effect of rising groundwater level on carbon emission by fire was estimated for the area 1 km far from the canal. The area was divide into 4 zones, Zone A: from the canal to 100 m far from canal, Zone B: from 100 m to 200 m, Zone C from 200 m to 500 m, Zone D from 500 m to 1000 m. The mean groundwater level I each zone was used the values along the line X_0–X_0' in Fig. 3. The amount of carbon emission was calculated by using the regression formula shown in Fig. 4 and shown in Table 1.

The amount of carbon emission after dam construction in Zone A was decreased to 46.4% of that before dam construction. The ration of carbon emission after the dam construction were 66.0% in Zone B, 71.8% in Zone C, 90.6% in Zone D respectively.

Around 50% of carbon emission by peat/forest fire in the area from canal to 200 m far from canal can be decreased by dam construction. Most of peat/forest fire is generally occurred in the area along road and canal with human errors. Decreasing of carbon emission by fire in the zone along the canal will make a ripple effect on carbon emission far from the canal.

Table 1. Controls of carbon emission from peatland by peat/forest fire with dam construction and firefighting activity.

	Changes of annual lowest groundwater level by dam construction				Fire fighting Extinction rate (%)		
Zone (m)	Dam	GWL (m)	C- loss (Gt/Mha)	C -loss (%)	50	70	100
A (100)	before	2.0	0.122	100			
	after	1.0	0.056	46.4	23.2	13.9	0
B (100)	before	1.9	0.115	100			
	after	1.3	0.076	66.0	33.0	19.8	0
C (300)	before	1.2	0.069	100			
	after	0.9	0.050	71.8	35.9	12.5	0
D (500)	before	1.2	0.069	100			
	after	1.1	0.063	90.6	45.3	27.2	0
Total (1000)	before		0.792	100			
	after		0.597	76.0	38.0	21.8	0

2.2 The firefighting effect on reduction of carbon emission by peat/forest fire

Pear fire occur generally from surface fire near the canals and roads, which burns the grass and organic materials on the ground with human mistake. So then, the area from canal or road to 200 far from them is very important area for peat/forest fire control. In generally, the fire in urban area is control by the fire service of local government and that in the forest area is control by firefighting team belong to the forest management bureau. The most of peat/forest fires occur in the derelict land after the farmer peat/forest fires. The firefighting teams of fire service of local government and forest bureau do not battle the fire in such areas because the area are out of their territories. The firefighting activity by people in local community is the most important, useful and effective for fighting on peat/forest fire. In general, the most important actionfor firefighting is the initial fire extinguishing. The compact firefighting system which was handled by local people is useful for the initial fire extinguishing (Takahashi et al., 2013).

The effect of firefighting on carbon emission by peat/forest fire was classified to three ranks, 50%, 70% and 100% (Table 1). The peat/forest fires farther more than 200 m from the canal and road are mostly caused by the spreading fire from the area near canal and road. So if 50% the peat/forest fire is extinguished by local firefighting team, 50% of carbon emission will be decreased. In the case of the firefighting effects 70% and 100%, the carbon emission by peat/forest fire will be decreased with same way.

Conclusions

Three activities, forest recovery, rewetting and firefighting, for reduction of carbon emission from tropical peatlands were evaluated and concluded as follows:

1. Forest recovery is necessary and important to prevent the surface layer of peatland become dry to high probability of ignition.

2. Rising of groundwater level by constructing dams is remarkably effective in the area from canal to 200 m far from canal. Carbon emission by peat/forest fire is reduced to around 50% of that without dam.
3. Firefighting by local community on the peat/forest fire is also very important to prevent the fire spreading. If 50% of peat/forest fire in the area from canal to 200 m far from the canal is extinguished, the carbon emission by peat/forest fire will be decreased to 50% of that without firefighting.

References

BabrauskasV (2003) Ignition handbook. Fire Science Publishers, Issaquah, USA.

Jaya Adi, Takada Masayuki, Hirano Takashi, Mishima Yoshio, Inoue Takashi, and Takahashi Hidenori, 2012: Moisture behavior of surface peat layer in areas of different surface cover and different ground condition during dry season in Central Kalimantan. Proceedings of International Symposium on Wild Fire and Carbon Management in Peat-Forest in Indonesia.

Kamiya M. and Kawabata S., 2003: Physical properties of peat in Central Kalimantan. Proceedings of the International Symposium on Land management in Southeast Asia, Bali, 2002, 341-345.

Shimada, S., Takahashi, H., Haraguchi, A. and Kaneko, M, 2001: The carbon content characteristic of tropical pets in Central Kalimantan, Indonesia: Estimating their special variability in density, Geochemistry, 53, 249-267, 2001.

Takahashi H., Yonetani Y. and Miyasaka H.,1998: Micrometeorological aspects oftropical peat swamp forest and farmland in Central Kalimantan, Indonesia. Proceedings of the International Workshop on Environmental Management ofWetland Ecosystem in Southeast Asia(Eds. Tokura, S.), 41-46.

Takahashi Hidenori, Usup Aswin, Hayasaka Hiroshi, Limin H. Suwido, 2003: Estimation of ground water level in a peat swamp forest as an index of peat/forest fire. Proceedings of the International Symposium on Land management in Southeast Asia, Bali, 2002, 311-314.

Takahashi Hidenori, Jaya Adi and LiminH.Suwido, 2013: Compact fire extinguishing system for firefighting teams of villages in peatland area of Central Kalimantan. Proceedings of International Symposium on Wild fire and Carbon Management in Peat-Forest in Indonesia, Palangka Raya, 2012, 203-206.

Usup Aswin, Hashimo Yoshihiro, Takahashi Hidenori and Hayasaka Hiroshi, 2004: Combustion and thermal characteristics of peat fire intropical peatland in Central Kalimantan, Indonesia. TROPICS, 14(1), 1-19.

Effect of the small drainage channels on the groundwater level of the Block C Area, Central Kalimantan, Indonesia

Koichi Yamamoto[1)*], Yoshiyuki Ishii[2)], Ken Koizumi[3)], Hiroshi Fukami[4)], Hidenori Takahashi[5)], Suwido H. Limin[6)], Kitso Kusin[6)], Aswin Usup[6)], and Gatot Eko Susilo[7)]

[1)] Graduate School of Science and Engineering, Yamaguchi University, Ube, Japan
[2)] Institute of Low Temperature Science, Hokkaido University, Sapporo Japan
[3)] Nippon Koei Co., Ltd, Tokyo, Japan
[4)] Geological Survey of Hokkaido, Sapporo Japan
[5)] Hokkaido Institute of Hydro Climate, Sapporo Japan
[6)] Palangkaraya University, Palangkaraya, Indonesia
[7)] Lampung University, Lampung, Indonesia

[*] E-mail address: k_yama@yamaguchi-u.ac.jp

In the ex-Mega Rice Project (ex-MRP) area in Central Kalimantan, Republic Indonesia, there are many small drainage channels which connect to the main canal excavated by local residents. However, these effects were not considered. Therefore, in this research, groundwater flow simulation including a small ditch geographical feature altitude data was performed. Research area is the Block C area of the ex-MRP area between the Kahayan River and Sebangau River in the Palangkaraya City, Central Kalimantan, Indonesia. Recently, small ditches are newly excavated at around Kalampangan Canal and connected to the Kalampangan Canal. The calculated area was 1.266 km x 7.000 km, from the Kahayan River to the junction of the Taruna Canal. As a result of the study, when the water level of the Kahayan River is low, groundwater drainage is enhanced by the small drainage channels. However, when the water level of the Kahayan River is high, there is an effect of rising groundwater level by redistribution of the backwater to the peatland through small drainage channels. In conclusion, groundwater level can be raised by the operation of the movable dams at the outlet of the small drainage channels.

Keywords: small drainage channel, peatland, groundwater.

Introduction

It is estimated that between 0.81 and 2.57 Gt carbon were released to the atmosphere in 1997 as a result of burning peat and vegetation in Indonesia (Susan et al., 2002). Peatland fire and forest degradation are great source of CO_2 emission. In the late 1990s, massive drainage canal excavation has been performed during the Mega Rice Project in tropical peat swamp forest in Central Kalimantan, Indonesia (Jaenicke et al., 2011). This massive drainage canal excavation has caused significant groundwater level decrease and soil drying within the surface peat layer. Many severe wildfires occurred in the extremely dry El Niño year (Langner and Siegert, 2009), leading to peatland degradation, which causes irreversible peat subsidence (Wösten et al., 1997). To protect the peatland from wildfires, it is necessary to maintain a high groundwater level in the peat layer, one of the most important restoration measures of tropical peatlands is blocking of drainage canals with dams and thus raising the groundwater level of the surrounding peatland (Suryadiputra et al., 2005),(CKPP, 2008), (Jauhiainen et al., 2008) and (Jaenicke et al., 2010). Rewetting effect by damming were evaluated using remote sensing (Jaenicke et al., 2011). However, in the Block C area in Central Kalimantan, there are many small drainage channels which connect to the main canal excavated by local residents. However, these effects were not considered into previous researches. In this research, groundwater flow simulation including a small ditches were performed to clarify the effect of them on the depletion of the groundwater table.

Methods

The study was conducted in Central Kalimantan Province, Indonesia. The area is lying between the Kahayan River and the Sebangau River and called 'Block C' of the Mega Rice Project area. Our study site is located 15 km southeast of Palangkaraya City, in the northern of Block-C area. There are two main canals, the Kalampangan Canal, which crosses the area from the Kahayan River to the Sebangau River, and the Taruna Canal, which starts at the junction of the Kalampangan Canal in the southeast direction. Peat samples are sampled at around Lg.1 in the Figure 2. These peat samples were taken from 0 to 200 cm deep and applied to water retention test. Water retention test was done with hand pump and ordinary filter holder with glass fiber filter. The wet peat samples were set on the glass fiber filter in the filter holder and pressure in the bottle was reduced by the handpump.

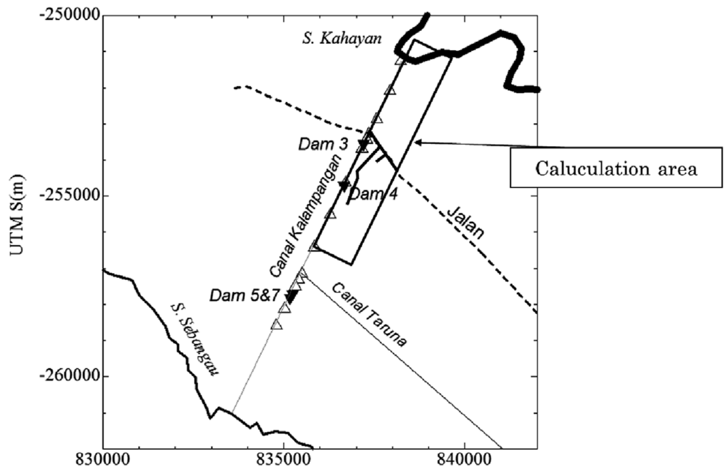


Figure 1. Study area and calculation area

Groundwater observation wells were installed in the Block C on July 2010 (Figure 1). Iron pipe of 20 mm in diameter was used as benchmark in each well. The length of the benchmark pipes is more than 3 meters. Our pipes completely penetrated peat layer and reached the subsurface layer. These benchmarks were measured by the static GPS observations. Observation period for one measurement of GPS was 30 minutes in 15 seconds interval. The vertical accuracy of the GPS is 5 mm plus 1.0 ppm of base line length. We determined the reference point as "BM3", which is the benchmark of Palangkaraya airport because national coordinate reference is not available in Central Kalimantan. All the data was calculated by Trimble Total Control and we used the geoid model, EGM 2008 to calculate coordinates. Spatial altitude data of the Block C are were derived from the Airborne Laser Scanner measured in Nov. 2009. Water level meters and barometers (OYO S&DL mini) were installed in the wells and started to measure water levels automatically. Water level meters take data for every 1 hour. Total of 31 shallow wells of 5 meter deep including existing wells were set to observe shallow groundwater in the surface peat. Deep groundwater wells are developed to observe groundwater levels of the sand layer around 20 m deep. All these wells have automatic water level meters. Also, water level gauges and loggers were installed in the Kalampangan Canal (7 points) and the Taruna Canal (4 points). The period of water level measurement was from February 2 to August 15, 2011. Numerical simulation of the groundwater table with or without small drainage system were performed in the Block C area of the ex-MRP area between the Kahayan River and Sebangau River in the Palangkaraya City, Central Kalimantan, Indonesia. The calculated area was 1.3 km x 7 km, from the Kahayan River to the junction of the Taruna Canal. Also the numerical simulation of the groundwater level around peat dam were performed. The simulation of the groundwater movement using Hydrus-3D software (Simunek, 2008). Governing Equation is shown in Eq. (1):

$$\frac{\partial}{\partial x}\left(K\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K\frac{\partial h}{\partial y}\right)+Q-S_s\frac{\partial h}{\partial t}=0 \qquad (1)$$

where K is hydraulic conductivity [L/T], h is head[L], SS is the specific yield[1/L], Q is the source / sink term [1/T]
The hydraulic conductivity T is used as 1.0×10-2 m/s (Koizumi et al; 2012) for the peat soil. Water retention curve was approximated by van Genuchten curve, Eq. (2):

$$\theta(h)=\frac{\theta s-\theta r}{\left[1+(-\alpha h)^n\right]^m}+\theta r \qquad (2)$$

where is the volumetric water content (-), is the saturated water content (-), is the residual water content, and are the constant, and =1/n. Boundary conditions is fixed water table for all the sections and no flux for east side of the area. Boundary condition of the water table is shown in Table 1. These water levels were derived from actual measuement result of the groundwater table data. Calculation terms are 30 days for each case with 4mm/day evaporation with no rainfall. Triangular prism mesh sizes are 180 m in horizontal and 10 cm in vertical axis (Figure 2 and Figure 3).

Table 1. Caluculation condition of the numerical simulation of groundwater

Number	Date	Boundary A [m]	Boundary B[m]	Boundary C[m]
1	January 1st	16.50	18.08	17.74
2	March 1st	17.36	18.09	18.61
3	May 1st	17.06	17.88	17.90
4	July 1 st	15.66	17.50	17.58
5	September 1st	15.39	17.08	17.45

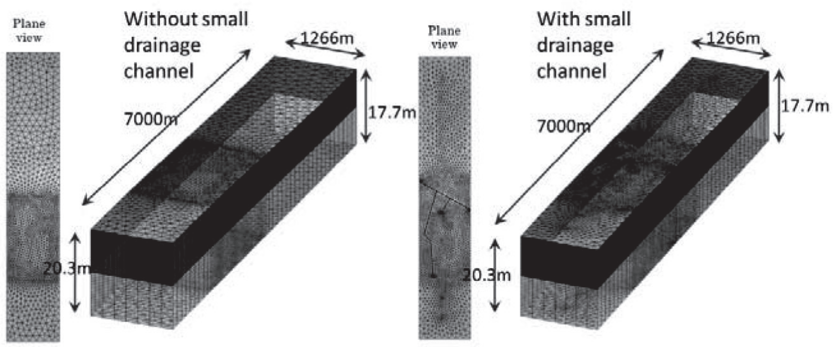


Figure 2. Finite Element Mesh of the Numerical simulation

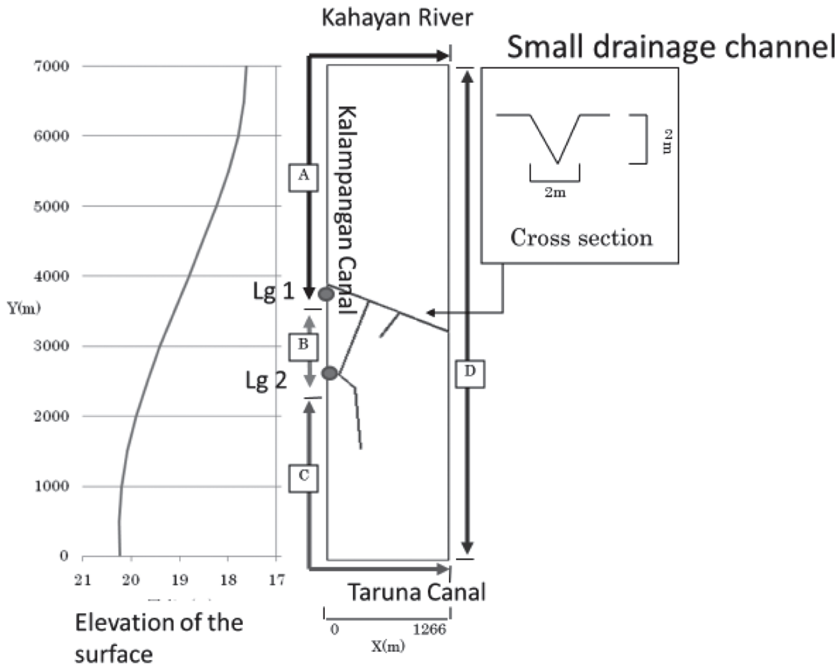


Figure 3. Detail of the calculated area of the numerical simulation

Results

As a result of the water retention experiment, the parameters of the water retention curve of peat soil were identified as shown in Table 2.

Figure 2. Finite Element Mesh of the Numerical simulation

Parameter	Value
saturated water content; θ_S[-]	0.895
residual water content; θ_S[-]	0.770
constant; α[cm^{-1}]	0.00406
constant; n	4.8

Simulated groundwater table without or with small drainage channels are shown in Figure 4 and Figure 5, respectively. Around the DAM3 (X=0m, Y=2500m), groundwater table gradients were steep in especially dry seasons (Jul. and Sep.). In the wet season (Jan. Mar. and May), groundwater table changes around DAM3 were not so clear. Most of all the results of the groundwater table shows that the groundwater table in the conditions with small drainage channels enhance dryness of the peat soil (Figure 6). However, simulated results of the groundwater table with small drainage channels shows that in the wet season, northern groundwater table in March was higher than without small drainage channels. The small drainage channels behaved as rewetting channel for the peatland in the wet season.

The effect of the small drainage channel will have decrease effect on groundwater level in dry season and it leads to the dryness of the peat. Increasing effect on groundwater level in wet season leads to the flood of the peatland. In other words, small drainage channels have a function of recharging to the peatland of lower elevation if the receiving river has high elevation of the water level.

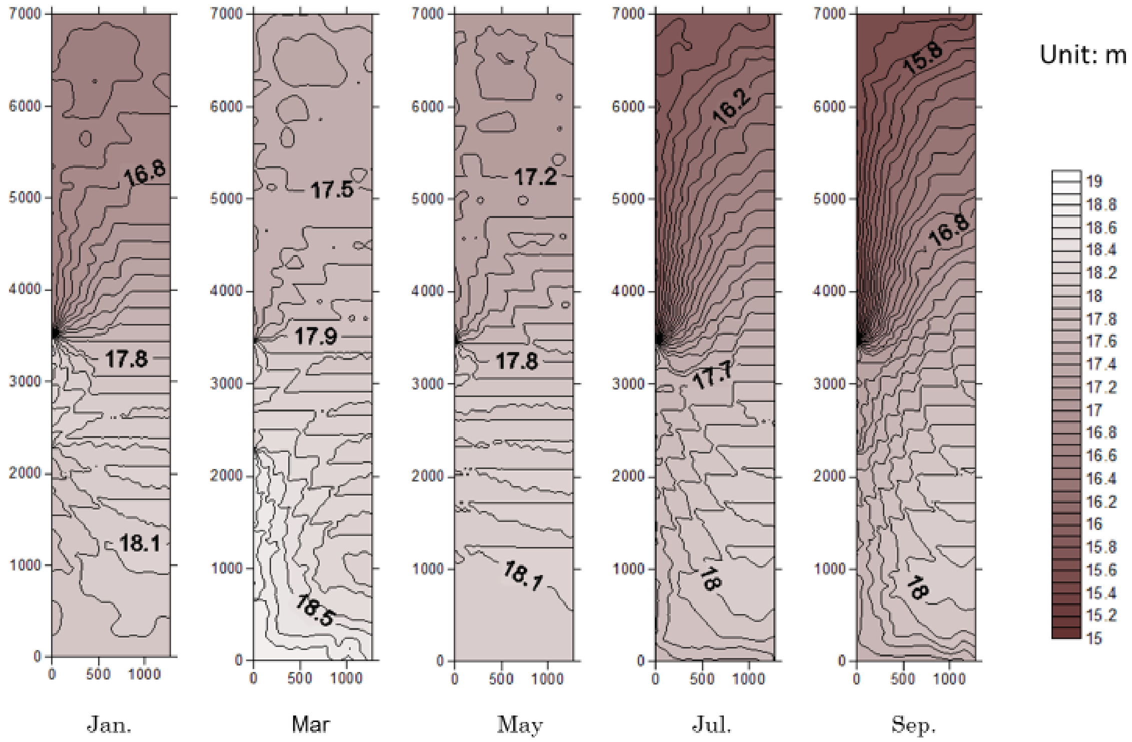


Figure 4. Result of the simulation of the groundwater table without small drainage channel

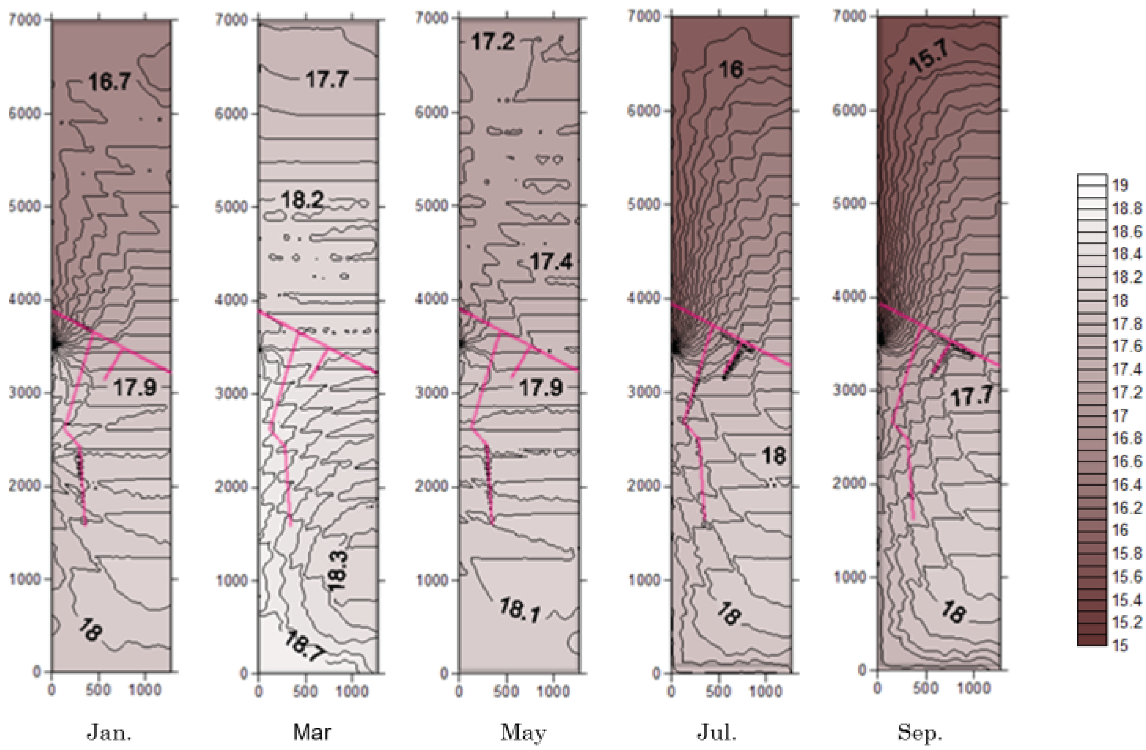


Figure 5. Result of the simulation of the groundwater table with small drainage channel

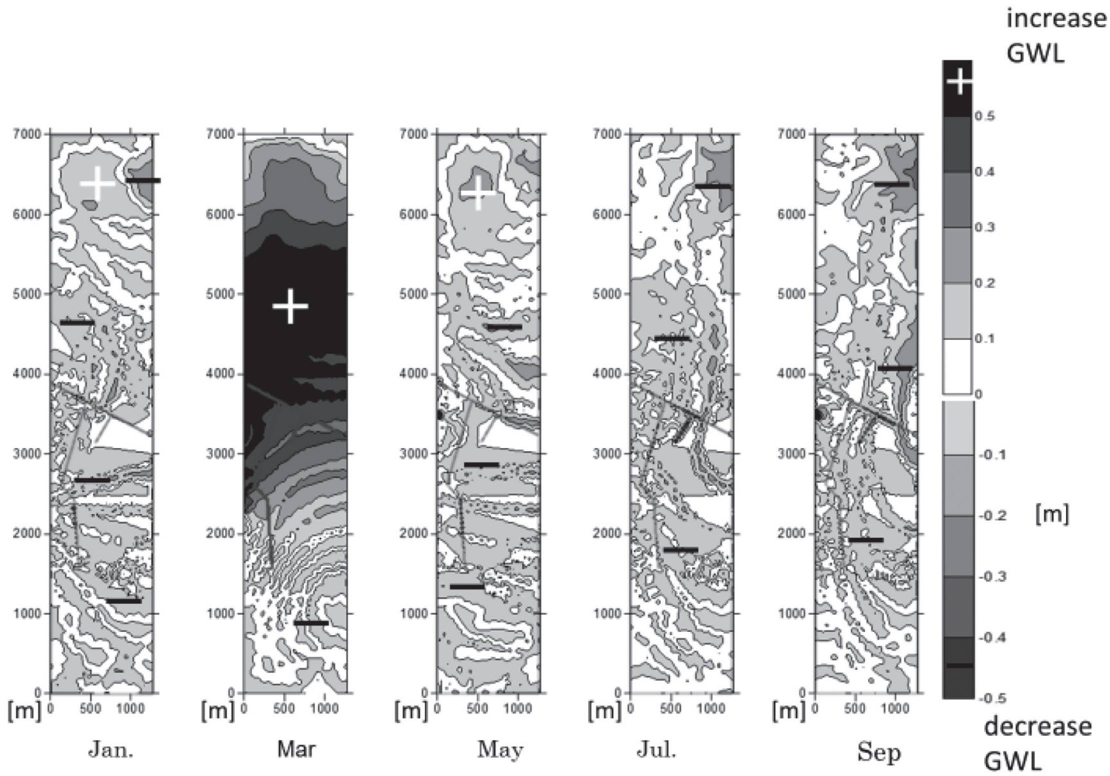


Figure 6. Result of the difference of the simulated groundwater level without small drainage channels subtract from the simulated results with small drainage channels

Conclusions

If water level of the canal is maintained in higher level, small drainage channels work as a recharge channel. In general, small drainage canals will cause groundwater level decreasing around 0.2 m – 0.3 m for large area. It is recommended to put peat dams or movable dams in small drainage channels to maintain the groundwater level.

References

CKPP (2008), Provisional Report of the Central Kalimantan Peatland Project, CKPP Consortium, Palangka Raya, Indonesia.

J. Jaenicke, J.H.M. Wösten, A. Budiman, F. Siegert (2010), Planning hydrological restoration of peatlands in Indonesia to mitigate carbon dioxide emissions, Mitig. Adapt. Strateg. Glob. Change, pp. 223-239.

J. Jaenicke, S. Englhart, F. Siegert (2011), Monitoring the effect of restoration measures in Indonesian peatlands by radar satellite imagery, Journal of Environmental Management, Vol. 92, Issue 3, pp. 630-638.

J. Jauhiainen, S.H. Limin, H. Silvennoinen, H. Vasander (2008), Carbon dioxide and methane fluxes in drained tropical peat before and after hydrological restoration, Ecology, 89 (12) , pp. 3503–3514.

A. Langner, F. Siegert (2009), Spatiotemporal fire occurrence in Borneo over a period of 10 years, Glob. Change Biol., 15, pp. 48–62.

I.N.N. Suryadiputra, A. Dohong, R.S.B. Waspodo, L. Muslihat, I.R. Lubis, F. Hasudungan, Susan E. Page, Florian Siegert, John O. Rieley, Hans-Dieter V. Boehm, Adi Jaya and Suwido Limin (2002), The amount of carbon released from peat and forest fires in Indonesia during 1997, Nature 420, pp. 61-65.

I.T.C. Wibisono (2005) A Guide to Blocking of Canals and Ditches in Conjunction with the Community, Wetlands International – Indonesia Programme, Bogor.

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

Simunek, J., van Genuchten, M.Th., Sejna, M., 2008. Development and applications of the HYDRUS and STANMOD software package and related codes. Vadose Zone J. 7 (2), 587–600.

Recent fire trends in Indonesia and SOI (Analysis using NOAA and MODIS hotspot data)

Hiroshi Hayasaka[1)]*, Nina Yulianti[2)] , Erianto I. Putra[3)], and Aswin Usup[2)]

[1)] Hokkaido University, N13 W8, Kita-ku, Sapporo, Hokkaido, Japan
[2)] Palangka Raya University, Central Kalimantan, Indonesia
[3)] Bogor Agricultural University, Bogor, Indonesia

E-mail address: hhaya@eng.hokudai.ac.jp

Analysis results of hotspot data in most recent 16-year period (1997-2012) identified fire prone areas in Kalimantan and Sumatra. Monthly hotspot analysis was newly introduced to show different temporal fire occurrence in Kalimantan and Sumatra. High correlation coefficient between monthly number of hotspots and SOI implied an advanced fire forecast.

Keywords: AVHRR, MODIS, hotspot, SOI, MRP, peat fire.

Introduction

Hotspot data captured by AVHRR (Advanced Very High Resolution Radiometer) on NOAA and MODIS (Moderate Resolution Imaging Spectroradiometer) on Terra and Aqua for the most recent 16-year period (AVHRR: 1997 to 2001, MODIS: 2002 to 2012) were analyzed to elucidate recent trends in the seasonal and spatial fire occurrence in Indonesia. Analysis using 0.5° × 0.5° grid cells was applied to identify most fire prone areas in Indonesia for future effective fire prevention. Recent authors' papers using MODIS hotspot data already cleared: major fire islands were Kalimantan and Sumatra in whole Indonesia, major fire prone areas in Kalimantan and Sumatra were MRP and Sampit area in Central Kalimantan, Dumai area in Northern Sumatra, and Palembang area in Southern Sumatra. In addition these areas, southern west coast area in West Kalimantan, southern interior areas in East Kalimantan, and Jambi areas in Southern Sumatra were added due to severe fire occurrences in mainly 1997 and 1998 detected by AVHRR.

Many scientists including the authors already cleared: Most fire incidents in Indonesia occurred during dry season and can be explained by precipitation amount and drought condition during dry season. Once El Niño event happened, peat fire could become active under prolonged rainless condition or drought. Thus, fire prediction carried out mainly by considering El Niño index. But sever fire occurrences such as Dumai area in 2005 and interior area in East Kalimantan in 1998, could not be explained well only by El Niño index. In this paper, another index of ENSO, SOI (Southern Oscillation Index) was introduced to evaluate severe fire occurrence in Indonesia by the authors. Preliminary analysis done by one of the authors clearly showed SOI values for severe fire years such as 1997, 2002, 2004, 2006, and 2009 were below -0.5. SOI values of severest fire year in 1997 were lowest and kept -1.5 during fire season. In addition, SOI values of around -1.6 from January to March in 1988 and 2005 could explain the above mentioned Dumai and interior area in East Kalimantan. Thus, the authors would like to suggest next future fire strategy in Indonesia should include SOI for an advanced fire forecast.

Methods

The study area covers Kalimantan and Sumatra Island. Analysis using a 0.5° grid cell was applied to clarify the spatial and seasonal fire occurrence in both islands. Number of grid cells was approximately 220 and 195 cells for Kalimantan and Sumatra respectively. In order to clarify spatial and seasonal fire occurrences in severe fire regions, the authors have given suitable names such as MRP+13, Dumai+12 and so on. Expression of such as "+13" after these region names just shows: "+" means extended area of each region, and "13" is number of grid cells. The borders of these regions are different from those used in conventional political and geographical maps.

Daily AVHRR and MODIS hotspot data for the most recent 16-year period (AVHRR: 1997 to 2001, MODIS: 2002 to 2012) were analyzed to elucidate recent trends in the seasonal and spatial fire occurrence in Kalimantan and Sumatra. AVHRR on NOAA hotspot data was from JICA-Sipongi collection and MODIS hotspot data (Collection 5.1 active fire product) was from the FIRMS website (Fire Information for Resources Management System, http:// earthdata.nasa.gov/data/near-real-time-data/data/firms).

ENSO (El Niño and Southern Oscillation) index was from the web site of Bureau of Meteorology, Australia Government (http://www.bom.gov.au/climate/current/soihtm1.shtml).

Results and Discussions

Fire Prone Areas in Kalimantan and Sumatra. The annual mean number of hotspots for each grid cell was shown in Figure 1 by using a solid circle. Diameter of each solid circle is defined proportionally to each annual mean number of hotspots. From Figure 1, the extreme high hotspot density cell (901 hotspots/yr.) was found in MRP (Mega Rice Project) area in Kalimantan. Other two very high hotspot density cells (666 and 632 hotspots/yr.) were also located in MRP area. In Sumatra, the second high hotspot density cell (686 hotspots/yr.) was found in Dumai area. Based on these four very high hotspot density cells, two most fire prone areas could be defined as MRP+ and Dumai+. Other fire prone areas were Palembang+, Sampit+, West Kalimantan-south, East Kalimantan, South and North Others (Sumatra), and West Kalimantan-north+interior.

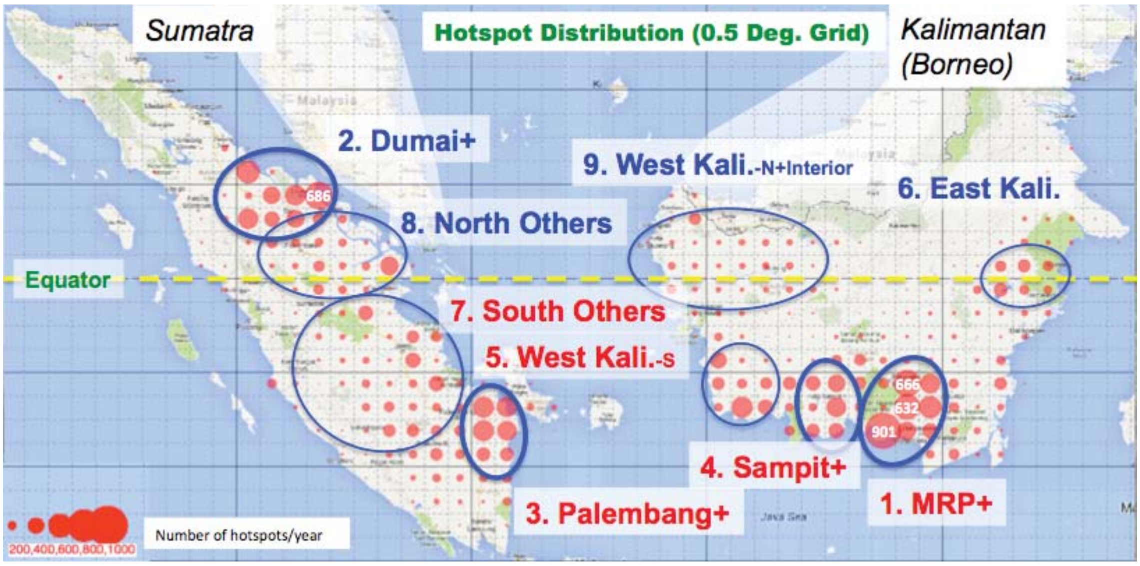


Figure 1. Fire prone areas in Kalimantan and Sumatra

Annual Fire Occurrence in Kalimantan and Sumatra. The annual fire occurrence in Kalimantan, the four provinces and the MPR+ region, during the most recent 16-year period (1997-2012), is shown with stacked bars in Figure 2. The unit of the Y-axis in Figure 2 is the number of hotspots. The stacked bar graph in Figure 2 shows the number of fires in the five regions, from top to bottom: East 79, West 57, South 16, Central 57, and MPR+13. Here, MRP+13 was specially extracted from Central 57 to show its fire occurrence trend. The annual mean numbers of fires in Sumatra was added in the one bar on the far right in Figure 2 for comparison.

In Figure 2, the annual mean number of hotspots in Kalimantan shown by a solid line was about 24,000 hotspots/yr. Fire activity of each year in Figure 2 clearly shows: the number of hotspots in the 16-year period varied by a factor of about 20 between the year with the most fires, 80,000 in 1997, and the year with the fewest, 4,000 fires in 2010. Since fire activity in 1997, 1998, 2002, 2004, 2006 and 2009 was higher than average, we may refer to them as "fire years (>24,000 hotspots)." The bar graph of the severest fire year, 1997, in Figure 2 showed: the number of hotspots in Kalimantan is about 80,000 hotspots/yr., about 47.5% of the fires occurred in Central Kalimantan and MPR+13 responsible for about 17.5% of the fires. Finally, we should note that constant fire occurrence in MPR+13 and East Kalimantan experienced severe fires under drought conditions in February and March of 1998 under strong El Nino conditions (Siegert and Hoffmann 2000).

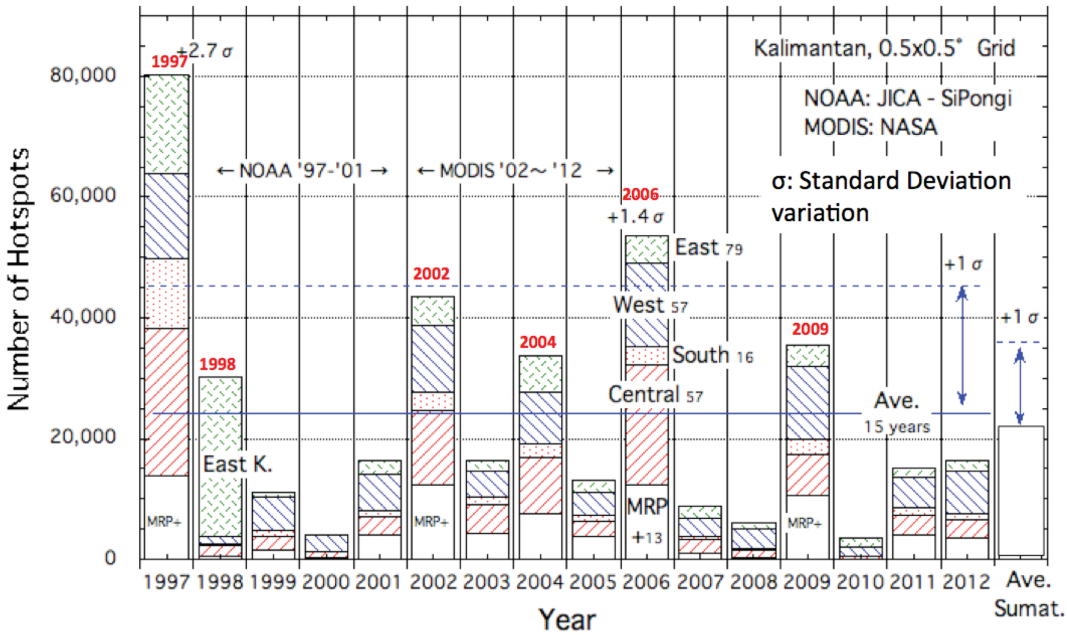


Figure 2. Recent trends in annual fire occurrence in Kalimantan

The annual fire occurrence in six regions in Sumatra, during the most recent 16-year period (1997-2012), is shown with stacked bars in Figure 3. The unit of the Y-axis in Figure 3 is the number of hotspots. The stacked bar graph in Figure 3 shows the number of fires in the six regions, from top to bottom: North others 72, Pekan Baru+11, Dumai+12, South others 64, Jambi+7, and Palembang+17. The annual mean numbers of fires in Kalimantan was added in the one bar on the far right in Figure 3 for comparison.

From Figure 3, the annual mean number of hotspots in Kalimantan shown by a solid line was about 21,000 hotspots/yr. Fire activity of each year in Figure 3 clearly shows: the number of hotspots in the 16-year period varied by a factor of about 9.3 between the year with the most fires, about 65,000 in 1997, and the year with the fewest, about 7,000 fires in 2010. Since fire activity in 1997, 2004, 2005, 2006 and 2009 was higher than average, we may refer to them as "fire years (>21,000 hotspots)." The bar graph of the severest fire year, 1997, in Figure 3 showed: the number of hotspots in Sumatra is about 65,000 hotspots/yr., about 90% of the fires occurred in South Sumatra. On the contrary, about 84% (=27,000/32,000) of the fires occurred in North Sumatra in

2005. From these different fire trends in North and South Sumatra, we may say that fires in North Sumatra tend to occur under different fire weather condition from South Sumatra.

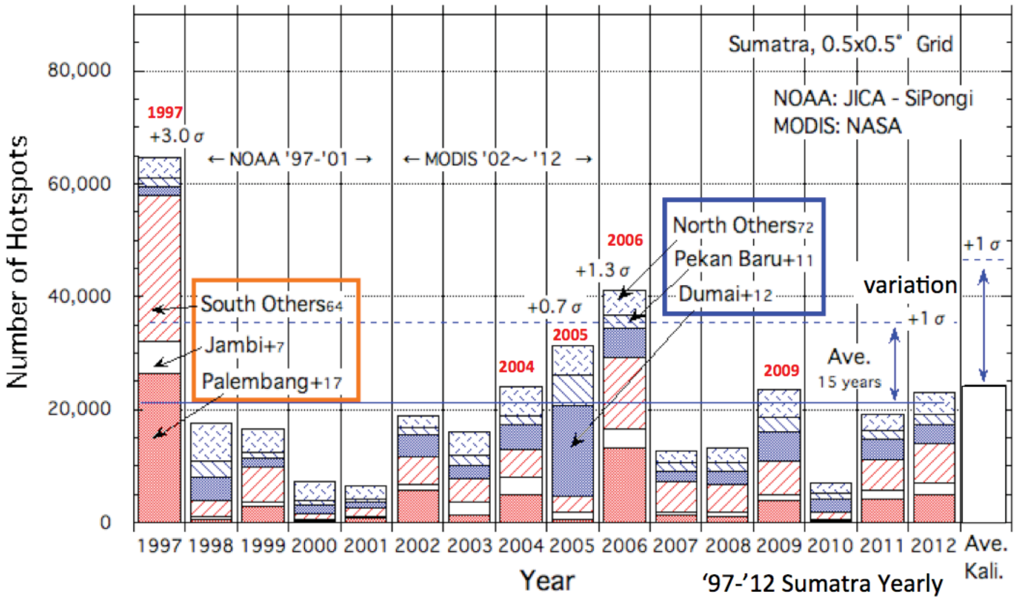


Figure 3. Recent trends in annual fire occurrence in Kalimantan

Monthly Fire Occurrence in Kalimantan and Sumatra. The monthly fire occurrence in Kalimantan and Sumatra were shown with two line graphs in Figure 4. The monthly fire occurrence can clearly show not only temporal fire occurrence and also monthly fire peak of each year. From Figure 4, most monthly fire peaks of each year in Kalimantan were larger than these in Sumatra. Largest monthly number of hotspots was about 38,000 hotspots in September in 1997 in Kalimantan. Other five severe fire peaks in Kalimantan occurred during from July to October in 2001, 2002, 2004, 2006, and 2009. One exceptional fire in Kalimantan was East Kalimantan fire in 1998. On the contrary, most of monthly fire peaks in Sumatra were smaller compare with those of Kalimantan. In Sumatra, there are a few fire periods in from January to March, June, and from July to October. Two largest monthly fire peaks in Sumatra in 1997 and 2006 were mainly due to fires in Palembang area. Winter fire peak in Sumatra in 2005 was made by fires in Dumai area. This winter fire trend in North Sumatra occurred under the effect of winter monsoon in the northern hemisphere.

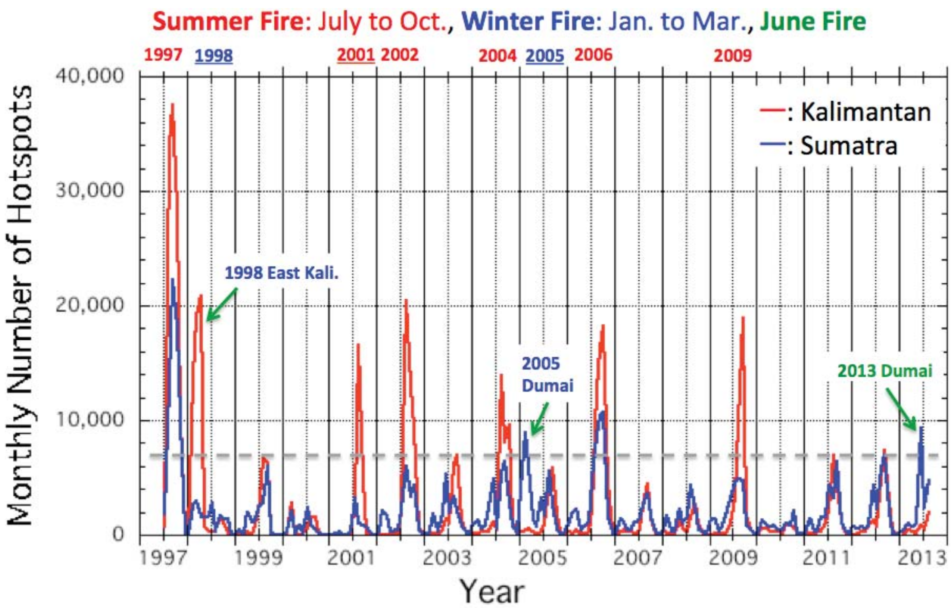


Figure 4. Monthly fire occurrence in Kalimantan and Sumatra

Monthly Fire Occurrence and ENSO. In Indonesia, severe fire occurred in every El Niño years like 1997, 2002, 2004, 2006 and 2009 under rainless or drought condition enhanced by El Niño. There are relatively strong correlations between ENSO index and rainless condition or fire occurrence. In Figure 5, monthly SOI and fire occurrence in Kalimantan were plotted to see their tendency. From Figure 5, most fire peaks of every years occurred when SOI became negative values. Correlation coefficient between peak monthly fire occurrence of each year and SOI of peak fire month of each year was R2=0.90. It was very high correlation coefficient compared with R2=0.81 for between peak monthly fire occurrence and Niño 3.4. In addition, correlation coefficient between peak monthly fire occurrence and SOI in previous month of peak fire month was still high, R2=0.80. This implied more effective fire forecast could be developed using SOI. In addition, SOI negative value of around -2 in Figure 5 could explain East Kalimantan fires in 1998 and Dumai fires in 2005.

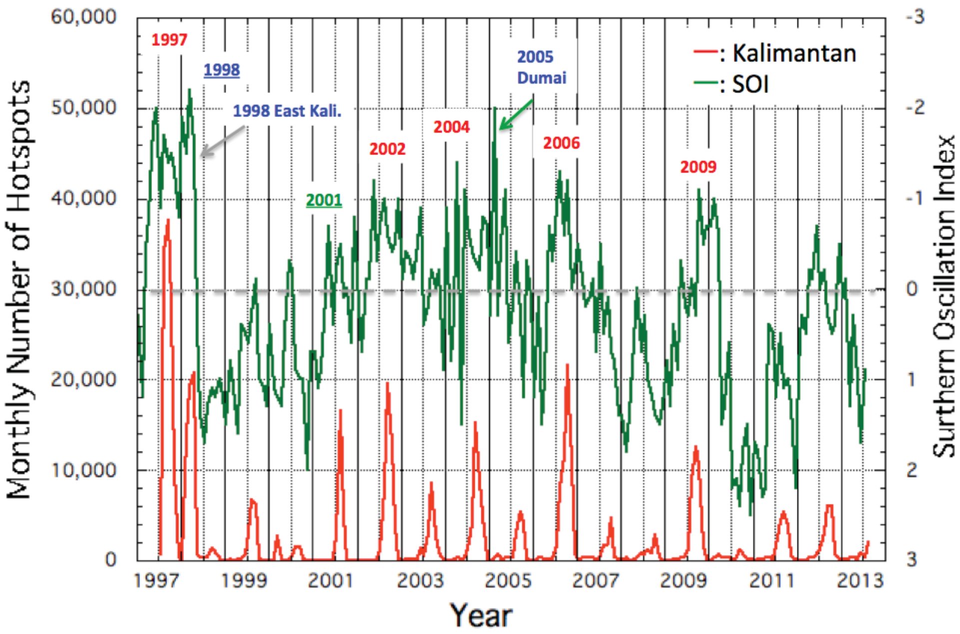


Figure 5. Monthly fire occurrence in Kalimantan and SOI

Conclusions

Hotspot data of the most recent 16-year period (AVHRR: 1997 to 2001, MODIS: 2002 to 2012) were analyzed to show recent trends in the seasonal and spatial fire occurrence in Kalimantan and Sumatra. Major fire prone areas in Kalimantan and Sumatra were MRP and Sampit area in Central Kalimantan, Dumai area in Northern Sumatra, and Palembang area in Southern Sumatra. In addition these areas, southern west coast area in West Kalimantan, southern interior areas in East Kalimantan, and Jambi areas in Southern Sumatra were added due to severe fire occurrences in mainly 1997 and 1998 detected by AVHRR.

Analysis using monthly number of hotspots was newly carried out to show different temporal fire occurrence in Kalimantan and Sumatra. High correlation coefficient between monthly number of hotspots and SOI implied an advanced fire forecast.

References

Siegert F, Hoffmann AA. (2000). The 1998 forest fires in East Kalimantan (Indonesia): a quantitative evaluation using high resolution, multitemporal ERS-2 SAR images and NOAA-AVHRR hotspot data. Remote Sensing of Environment, 72: 64-77.

Floristic diversity and the distribution of selected species in the peatland ecosystem in Central Kalimantan

Joeni Setijo Rahajoe[1)], Laode Alhamd[1)], Tika D Atikah[1), 2)], Bayu A Pratama[1)], Suhardjono[1)], Satomi Shiodera[2)] and Kohyama Takashi[2)]

[1)] Research Center for Biology - Indonesian Institute of Sciences. Cibinong Science Center Jakarta – Bogor KM 46 Bogor, West Java
[2)] Faculty of Environmental Earth Science Hokkaido University – Kitaku Kita 12 Nishi 8

Tropical peatlands have accumulated huge amount of carbon and are responsible for enormous carbon emissions every year. However, the carbon pool is presently disturbed by land management, and consequently has become vulnerable. Tropical peatlands present the threat of switching from a carbon sink to a carbon source in the atmosphere, and also provide a number of ecosystem services including biodiversity, habitat, water cycling, and commodity products. Tree diversity in the peat swamp forests were described in various study sites in Central Kalimantan. Tree species were recorded to total about 394 in Sebangau, Bawan, and Hampangen villages, these trees species were only about 42.5% of the total tree species which were found in the peat swamp forest. About 349 tree species were found in the peatswamp and heath forests.Tree species distribution of some leading trees such as: Shorea rugosa, Shorea teiysmanianna, Dryera costulata, and Callophyllum lanceolatum were discribed as well.

Keywords: Above ground biomasa, Central Kalimantan, litterfall, peat swamp forest

INTRODUCTION

Almost half of tropical peatlands supporting the growth of peat swamp forests are in Indonesia. Tropical peat swamp forests in Indonesia store huge amounts of carbon and are responsible for enormous carbon emissions every year due to forest degradation and deforestation. These forest areas are in the focus of REDD+ (reducing emissions from deforestation, forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks) projects, which require an accurate monitoring of their carbon stocks or aboveground biomass (AGB).Peat degradation occurs most rapidly and massively in Indonesia, because of fires, drainage, and deforestation of swamp forests coexisting with tropical peat.Deforestation and forest degradation in the tropics is a major source of global greenhouse gasemissions. At the end of the extreme dry season in 1997 (caused by ENSO), the biggest fires broke out over almost all forest types in Kalimantan and Sumatra Island. Forest fires have enormous impacts on the tropical forest ecosystems and biodiversity. The estimated extent of spatial damage by fire during 1997-1998 in Kalimantan were 75,000 ha of peat swamp forest, 2,375,000 ha of lowland forest, 2.829.000 ha of land for agricultural, 116.000 ha of timber plantation, 55.000 ha of estate crops and 375.000 ha of dry scrub & grass land, in total was 6,500,000 ha. Frequent forest fires occurred during the past ten years, and repeated cycles of burning have completely transformed forests into grasslands or scrublands. Decreased of species diversity was also recorded in the peat swamp forest due to frequent forest fire in the selected research area (Klampangan, Bawan and Hampangen peat swamp forests)

More than half the world's threatened species are recorded in the tropics, and tropical peatlands provide a number of ecosystem services, including biodiversity, habitat, carbon and water cycling, and commodity products. and raising the possibility that reducing GHG emissionscould provide substantial co-benefits for biodiversity conservation and ecosystem services. The tropical peat swamp forests of Indonesia are unusual ecosystems that are rich in endemic species of flora, fauna and microbes despite their extreme acidic, anaerobic, nutrient poor conditions. About 3.1 – 6.3 Mha of peat swamp forest are recorded in Kalimantan (Silvius 1989, Rieleyet al. 1996).

There are over 15.000 different flowering plants in Borneo and over 3000 tree species,ofwhichman yareendemictotheisland.Areasonforthishuge species abundanceisthedistinctecosystems,suchasthev arioustypesofforest,thatcanbefoundacrossBorneo. At least 5,575 higher plant species were found in Kalimantan, 71 lichens, 376 mosses, 235 fungi and other families (Anonim, 2011). The aims of the research to estimated the flora diversity and the tree composition in the peat swamp forest in Central Kalimantan.

Study sites and Methodology

Three locations were observed to describe the flora diversity, those were the peat swamp forests in Sebangu, Hampangan and Bawan Vilages. Those three villages were located in Central Kalimantan. The distance were about 30 until 80 km from Palangkaraya, the Capital City of the Central Kalimantan Province. Central Kalimantan, is the biggest province on the island of Kalimantan, it occupies about 153,800 Km2. The area mostly covered by forest about 67%, while swamps, rivers, lakes take approximately 2% (Anonim 2001). Majority of area topographic is flat for around 32.97%, hilly area is 9.83% and the area of extreme slope is 40%. The annual precipitation in Palangkaraya was 2731 mm (average from 1989 to 2008). Monthly rainfall was in the range of 153.5 - 303.1 mm, and below 100 mm in a few months of the dry season. The annual mean temperature varies between 26.8 - 28.1°C. The lowest annual rainfall was recorded on 1996, 2001 and 2004, while the higest annual temperature was recorded on 1998, a year after the biggest forest fire broke out in Central Kalimantan.

Detailed locations were described as followed: Bawan villages elevation is about 25 m above sea level, with the area is about 87 Km2. Most of the area was covered by the heath forests, with scattered patches of peat swamp forest (Fig 1). Hampangen was the nearest location from Palangkaraya about 20 km. Forest condition mainly is peat swamp forest and some of area are degraded due to the landuse

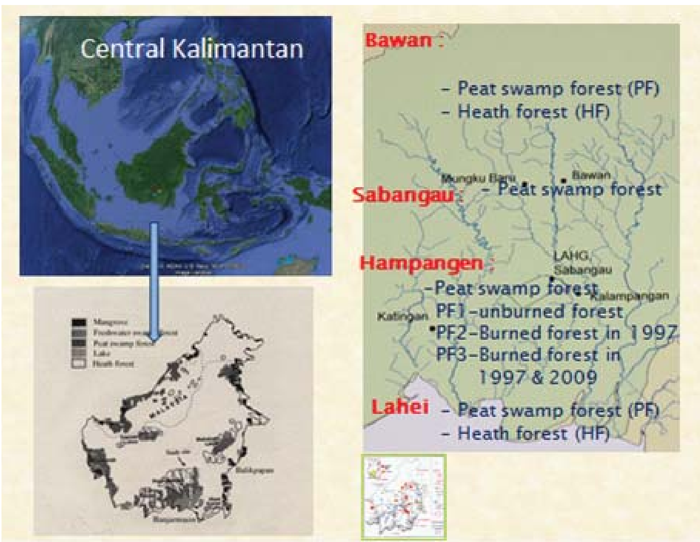


Figure 1. Peat Swamp forest permanent plots in Central Kalimantan.

change into agricultural farming or selective logging area before 1980's. Sebangau peat swamp forest is a part of Sebangau National Park, near Sebangau River, a blackwater river. The peat swamp forest in Sebangu is a dual ecosystem, with diverse tropical trees standing on the 3m – 12 m of peat.

Ecological study were carried out in each location, 1 ha permanent plot was established in each study site with the size 100 x 100 m2, and the plots was divided in to 100 sub plots with the size of 10 x 10 m2. These permanent plots were monitored annually. All trees in the permanent plot were recorded and measured the DBH (Diameter at Breath Height).

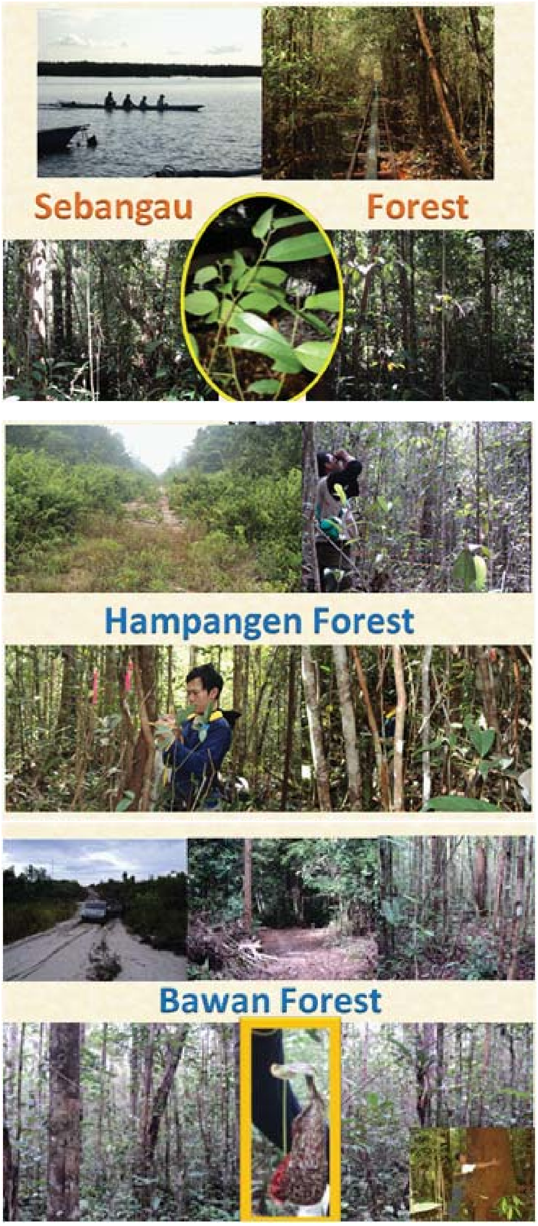


Figure 2. Study sites were in Sebangau (Upper), Hampangen (Middle), and Bawan Peat Swamp forests (lower).

About 927 species of flowering plants and ferns were recordedIn Borneo peat swamp forest (Yule 2010), while in Peninsular Malesia recorded around 260. Tree species in our study sites were about 103, 134, 45 in the Sebangau, Hampangen, and Bawan Villages, respectively. About 808 tree species were recorded for peat swamp forest in Sebangau(WWW, 2006).

Dominant Tree Species Distribution

From the ecological study we described the tree species distribution especially for selected some leading species in the permanent plots. The distribution of Shorea rugosa (Upper left), andShorea teysmanniana (Upper right) were shown in the Figure 4.Shorea rugosa was found only in the heath and peat swamp forests in Bawan Village. While Shorea teysmanniana was recorded almost in all four permanent plots in Bawan (peat swamp and heath forest), Hampangen (peat swamp forest), and Sebangau Villages (peat swamp forest).

The distribution of Shorea rugosa was recorded in Central, Northen and Eastern part of Kalimantan, While for Shorea teysmanniana wasrecorded in theCentral, Western, Northern and Eastern parts of Kalimantan, and this species widely distributed in Sumatera Island as well (Figure 4).

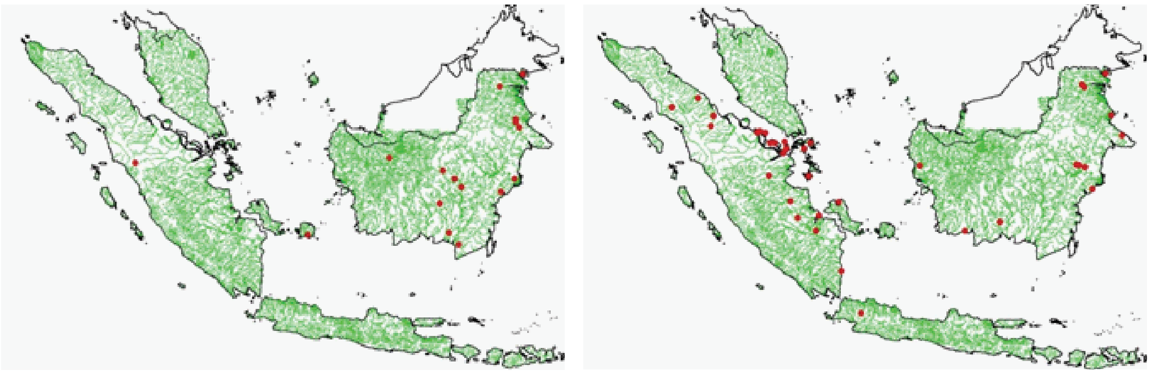


Figure 3. Tree species distribution of some leading species in the permanent plots, Shorea rugosa (Upper left) Shorea teysmanniana (Upper Right).

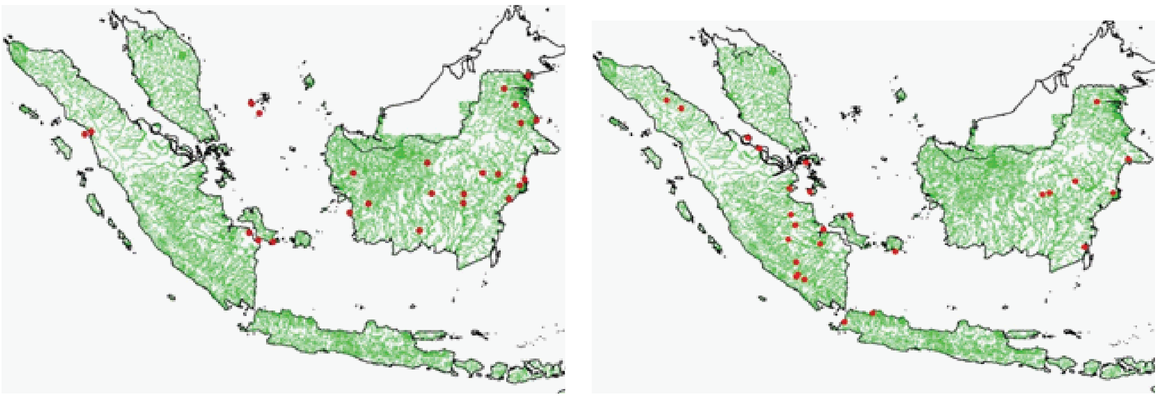


Figure 4. The distribution of Callophyllum lanceolatum(Upper left) and Dyera costulata (Upper Right).

C. lanceolatum distribution was recorded in the western, Eastern, Central and Nortern part of Kalimantan, and some part in the Sumatera, while the distribution of D. costulatum was recorded in the Eastern and Central Kalimantan and almost widely distributed in the West Sumatera (Figure 4). D. costulatum was found in all permanent plots in Bawan, Sebangau and Hampangen permanent plots, while C. lanceolatum only was found in the Bawan and Sebangau permanent plots.

References

Anonim, 2011. Status keanekaragamanhayati Indonesia, Maryanto I, Widjaya EA, Wowor D, Prijono SN (Eds). LIPI Press, Jakarta.

Rieley JO, Ahmad-Shah AA, and BradyMA.1996. The Extent and Nature of Tropical Peat Swamps. In Ed MaltbyE, ImmirziCP, and Safford RJ (Ed) Tropical lowland peatlandsof Southeast Asia. Proceedings of a Workshop on Integrated Planning and Management of Tropical Lowland Peatlands held at Cisarua, Indonesia, 3-8 July 1992. IUCN. pp. 17-53.

Silvius, M.J. 1989. Indonesia. In: Scott, D.A. (compiler) A Directory of Asian Wetlands,

IUCN, Gland, Switzerland and Cambridge, 981–1109.

Yule CM, 2010, Loss of biodiversity and ecosystem functioning in Indo-Malaya peat swamp forests. Biodiversity and Conservation. 19: 393-409.

Relationship between hydrochemical conditions and variation in forest and grassland communities in peat swamps of Central Kalimantan, Indonesia

Kazuo Yabe[1)]*, Satomi Siodera[2)], Takashi Kohyama[2)], Takatoshi Nakamura[3)], Eizi Suzuki[4)]

[1)] Faculty of Design, Sapporo City University, Sapporo, Japan
[2)] Faculty of Environmental Earth Science, Hokkaido University, Sapporo, Japan
[3)] Faculty of Bioindustry, Tokyo University of Agriculture, Abashiri, Japan
[4)] Faculty of Science, Kagoshima University, Kagoshima, Japan

* E-mail: k.yabe@scu.ac.jp

The purpose of this study was to clarify the hydrochemical factors controlling the distribution of the communities of trees and grasses. In particular, the importance of oxidation–reduction state (Eh value) was evaluated. Reduced soils are produced by activity of anaerobes, and harmful for plants owing to the oxygen deficiency and/or toxicity of reduced substances.

Keywords: Combretocarpus rotundatus, Kerapah shrub, mixed swamp forest, oxidation–reduction potentials, peat–pore water, pneumatophores, riparian grassland

Introduction

Natural wetland communities in tropical humid climates in Central Kalimantan, Indonesia, show a marked diversity in physiognomy and composition of plant communities across sites.

Recently, the peat swamp forests in southeast Asia have been drastically reduced in area and degraded, resulting in decreased biodiversity, increasing CO2 emissions and a loss of other ecosystem services (Miettinen & Liew 2010, Page et al. 2011, Yule 2010). Accordingly, fundamental ecological information is needed to restore the degraded peat swamp forests.

The species compositions in swamp forests in Central Kalimantan are strongly affected by the intensity and/or frequency of flooding, as indicated by their distance from rivers (Mirmanto 2010, Mirmanto et al. 2003). Flood tolerance of plants is related not only to the height of the water table but also to the redox intensity of the soil, which considerably influences plant functioning and growth (De Mars & Wassen 1999, Pezeshki & DeLaune 1998). Plant communities in warm-temperate marshes often encounter stresses associated with strongly reduced conditions (Yabe 1985, Yabe & Numata 1984), because higher temperatures enhance the activity of anaerobes (Ponnanmperma 1972). Accordingly, we expect soil reduction to be particularly important in tropical wetland communities, although knowledge of soil redox properties in tropical wetlands is limited (Haraguchi & Yabe 2002).

The objective of the present study was to identify the factors controlling the variation and composition of swamp plant communities by comparing forest, shrub, and grassland environments in Central Kalimantan.

Methods

We chose three tree communities showing distinct physiognomies and a riparian grassland. The study sites were all located in two areas in isolated river basins (Lahei and Setia Alam, ca. 50 km apart) that were 120 km and 150 km inland from the coast of the Java Sea, in Central Kalimantan Province, Indonesia. Earlier ecological investigations of community structure and species composition have been performed in this area (Page et al. 1999, Suzuki et al. 1998). Lahei is 3 to 4 km east of Babgus village (ca. 40 m above sea level; 1o 55′ S, 114o 08′ E) in the catchment of the Mangkutup River, a tributary of the Kapuas River. Setia Alam (2o 19′ S, 113o 54′ E) is located in the eastern side of the upper catchment of the Sebangau River.

Figure 1. Landscape of four communities

1) Mixed swamp forest: This community is a peat swamp forest mixed with several closed-canopy forest types (Anderson 1983). In Lahei, large trees of Shorea balangeran (Korth.) Burck, Buchanania spp. and Semecarpus spp. are dominant (Suzuki et al. 1998). The trees stand on hummocks that are 1−1.5 m tall and 2−3 m wide, formed from tree roots and their remains (Nishimura et al. 2007). Peat has accumulated to depths of 7.5 m (Haraguchi et al. 2000).

2) Riparian forest: This forest occupies the fringes of the extensive peat dome in Setia Alam. Although it may be considered a type of mixed swamp forest, we call it riparian forest because its physiognomy differs from that of the mixed swamp forest in Lahei. The canopy is partially closed and is formed by Combertocarpus rotundatus (Miquel) Danser., Tristaniopsis obovata (Benn.) Wilson & Waterhouse, Parastemon spicatus Ridley, Cratoxylum arborescens (Vahl) Blume, and Xylopia sp. Peat depth is 1−2 m (Table 1). The ground surface is higher than that of the riparian grassland and is not flooded by the river during the wet season.

3) Kerapah shrub (waterlogged heath shrub): This community, which has an open canopy and many low trees (<10 m high), occurs frequently in Lahei. Cratoxylum glaucum Korth. and Combretocarpus are dominant and there are some Dactylocladus stenostachys Oliv. In the wet season, many pools of brown water 5−15 cm deep develop and Sphagnum junghuhnianum Dozy & Molk and the soft respiratory-roots of Combretocarpus (2−3 mm in diameter) grow under submerged conditions. Many robust pneumatophores of Dactylocladus (30−40 cm tall and 2−3 cm in diameter) emerge vertically from the surface. The soil of this community is about 40 cm thick and is composed of a surface peat layer and a second layer of silica sand overlaying hard bedrock made of cemented silica particles (Table 1).

4) Riparian grassland: In Setia Alam, a 1−1.5 m tall grassland dominated by sedges, Gahnia cf. javanica Moritzi and Scleria oblata S.T. Blake ex J. Kern is widespread throughout the riparian zone of the Sebangau River. Ploiarium alternifolium (Vahl) Melch., a 1−2 m tall woody plant, and Pandanus sp. are mixed with the grassland. Peat depth in this community is 0.5−2 m (Table 1). The peat surface is covered by shallow flood water from the river during the wet season.

We examined the oxidation−reduction potential (Eh) and other hydrochemical conditions late in the wet season (i.e., January and March, from 2000 to 2002). At this time of year, water levels are usually highest and anaerobic conditions are generally present in wetland soils.

Water level, Eh in the soil profile, and pH and electrical conductivity (EC) of peat pore water were measured in each community.

Results and Discussions

Size, abundance, and species richness of trees decreased from mixed swamp forest through riparian forests to Kerapah shrub. Trees in the Kerapah shrub were stunted and showed special adaptive features for submergence, such as abundant respiratory roots emerging from the surface. High pH, high content of SO42- and low contents of Na+ and Ca2+ characterized the mixed swamp forest only (Table 2, 3), but Eh values were relevant to the distribution of all communities (Table 4). Shallow Eh values were lowest in the riparian grassland, indicating anaerobic condition that prevented the tree growth (Table 4). Deep Eh values were also lower in the Kerapah shrub than in other forests (Table 4), indicating strongly anaerobic deep soil that restricted the tree growth (De Mars & Wassen 1999, Pezeshki & DeLaune 1998). Therefore, the soil oxidation–reduction state is important for the differentiation of swamp forests.

Acknowledgement

The authors thank Dr. Suwido H. Limin and the staffs and students of CIMTROP at the University of Palangka Raya for the extensive research help they provided. The plant species of Setia Alam were identified by Dr. Erna Shinta of CIMTROP Herbarium and the Research Center for Biology, LIPI, Indonesia.

References

ANDERSON, J. A. R. 1983. The tropical peat swamps of western Malaysia. Pp. 181-199 in Gore, A. J. P. (ed.) Ecosystems of the World, Volume 4B, Mires: Swamp, Bog, Fen and Moor, Regional Studies. Elsevier, Amsterdam.

DE MARS, H. & WASSEN, M. J. 1999. Redox potentials in relation to water levels in different mire types in the Netherlands and Poland. Plant Ecology 140: 41-51.

HARAGUCHI, A., SHIMADA, S. & TAKAHASHI, H. 2000. Distribution of peat and its chemical properties around Lahei in the catchment of the Mangkutup River, Central Kalimantan. Tropics 10: 265-272.

HARAGUCHI, A. & YABE, K. 2002. Vertical and horizontal distribution of redox potential of soil in wetland forests in Lahei in Central Kalimantan, Indonesia. Tropics 11:91-100.

MIETTINEN, J. & LIEW, S. C. 2010. Degradation and Development of peatlands in peninsular Malaysia and in the islands of Sumatra and Borneo since 1990. Land Degradation and Development 21: 285-296.

MIRMANTO, E. 2010. Vegetation analyses of Sebangau peat swamp forest, Central Kalimantan. Biodiversitas 11: 82-88.

MIRMANTO, E., TSUYUZAKI, S. & KOHYAMA T. 2003. Investigation of the effects of distance from river and peat depth on tropical wetland forest communities. Tropics 12: 287-294.

Integration of responce and recovery processes of peat forests to human-induced disturbance into terrestrial ecosystem management

Satomi Shiodera[1)]*, Tika Dewi Atikah[2), 3)], Ismail Apandi[3)], Tatsuyuki Seino[4)], Akira Haraguchi[5)], Joeni Setijo Rahajoe[3)], Kazuo Yabe[6)], Takashi S. Kohyama[7)]

[1)] Center for Southeast Asian Studies, Kyoto University, Kyoto, Japan
[2)] Graduate School of Environmental Science, Hokkaido University, Japan
[3)] Research Center for Biology-LIP I, Cibinong, Indonesia
[4)] Faculty of Life and Environmental Sciences, University of Tsukuba, Japan
[5)] Faculty of Environmental Engineering, The University of Kitakyushu, Japan
[6)] School of design, Sapporo City University, Japan
[7)] Faculty of Environmental Earth Science, Hokkaido University

* E-mail address: sshiodera@gmail.com

The purpose of this study is to identify response and recovery processes of peat forests to human-induced disturbance in terrestrial ecosystem in Central Kalimantan. We conducted multi-level researches and clarified that keeping groundwater level was most important for forest recovery in peat swamp forest.

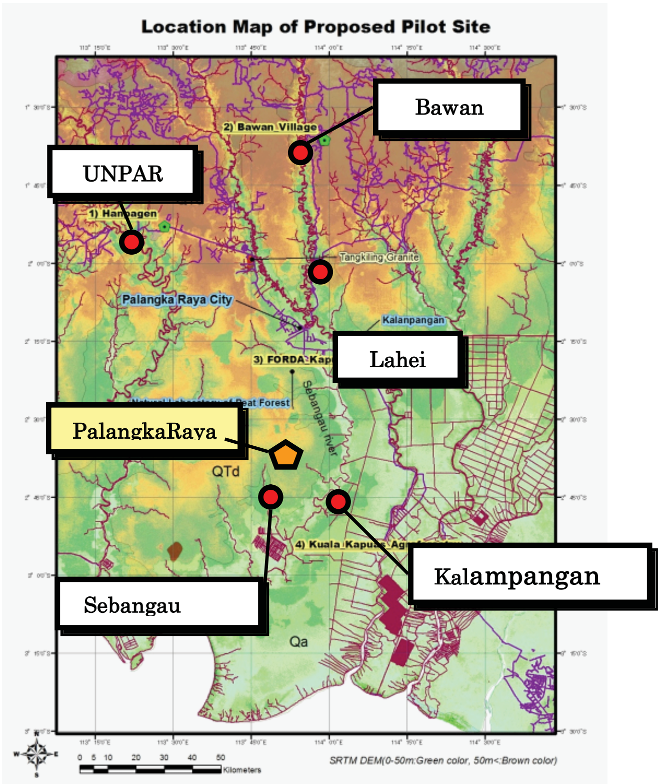
Keywords: forest recovery, peat fire

Introduction

Tropical peat swamp forests are unique ecosystems, because of their extreme acidic, anaerobic and nutrient poor conditions. They support diverse forms of flora, fauna and microbes with many endemic and endangered species. Anderson (1963) recorded 927 species of flowering plants and ferns in the peat swamp forests of Borneo. Most of the tree families that are present in lowland dipterocarp forests are also presented in peat swamp forests, but many of the species in peat swamp forests are specific to this habitat (Yule CM, 2010). They are also an important refuge for many endangered species including orangutan. However, peat fire has been a serious problem since the last decade in Central Kalimantan. Peat fire is a major cause of peatland degradation that leads to loss of biodiversity and carbon stock in peat swamp forests. When peat is ignited, fire will develop underground slowly and may spread vertically and horizontally dominated by smoldering process. Finally, peat fire will destroy ecosystem completely and change the environment drastically. Because, peat swamp forests are sustained in the sensitive balance among deep water table, canopy cover and leaf litter inputs (Yule CM, 2010), forest recovery would be difficult after a fire. In this study, we evaluated the response and recovery processes of peat forests to human-induced fire disturbance in multi-level researches and integrate them for reforestation.

Materials and Methods

We selected six sites for our studies in Central Kalimantan. There were 1) Kalamapangen, 2) Sebangau (Setia Aram), 3) Hampangen Educational Forest (HEF), 4) Bawan village, 5) Lahei and 6) others. We conducted multi-level researches to identify the response and recovery processes after human-induced disturbance in peat swamp forest.



The details of sites are as follows:

1) Kalampangen

The site is located 2.34ºS and 114.04ºE. It's around 25 km from Palangka Raya city. LIPI team set some permanent plots there. The plots were settled in drained, and burnt forest. They compared the recovery processes after peat fire.

2) Sebangeu (Setia Aram)

The natural peat swamp forest is founded in Sebangau (2°18' 24" S, 113° 55' 4.1" E, at about 10 m above sea level). It belongs administratively to Kereng Bangkirai village about 20-km southwest of Palangka Raya city. The area has been declared as the Natural Laboratory of peat swamp forest, which is part of a very large peat-covered landscape between Katingan River to the west and Kahayan River to the east, with total area of approximately 9,200 km. Sebangau study site is categorized as temporary flooded forest, with the peat layer depth is from 2 to 10 m in Sebangau study site. Some sites have been disturbed due to the impact of selective logging about ten years ago. Dr. Mirmant established fourteen permanent plots of 50 m x 50 m (0.25 ha) in the three study sites (Sebangau, Lahei and Tanjung Putting). Spatial variation in plant community was evaluated with the effect of distance from river stream and peat depth, based on the parameter recorded in 14 plots (Mirmant et al. 2003). All trees with 15 cm DBH (diameter of breast height) were recorded in their taxa and girth. Based on the girth, basal diameter of each tree was calculated.

3) Hampangen Educational Forest (HEF)

Hampangen Educational Forest (HEF) of University of Palangka Raya is in Kabupaten Kasongan. HEF is situated at 1°53´S and 113 °28´ E, at 42 m above sea level. The entire area of 5,000 ha HEF is covered by about 4-6 m shallow peat soil. Palangka Raya is located about ca. 70 km south-southeast of the study site. In rainy season, some parts of HEF will be flooded by long spell rain. On the other hand, in dry season, some parts of HEF will suffer severe damage by peat fire. In consequence, the mixed distribution of un-burnt and burnt forests is created in the HEF. The forest area including two of the research transects started to be deforested since September 2012. Three 0.2 ha (20 m × 100 m) transects were established in the peat swamp forest in December 2010. To identify the impact of peat fire to the forest recovery, the plots were set up according to disturbance severity by peat fire. They were located in un-burnt forest, burnt forest in 1997, and burnt forest in 1997/2009, respectively. The topography of the study site was generally flat. All trees with GBH (girth at breast height) more than 15 cm within the plots were identified to species and recorded.

4) Bawan village

We established 1 ha plot in peat and heath forest in Bawan village. The re-measurement was conducted each two years to calculate forest dynamics parameters. The research of allometory of tree saplings also carried out there.

5) Lahei

The Lahei site is located at 1° 55' 15" S and 114° 1 0' 0" E, at about 20 m above sea level. The area is belonging to Dusun Babugus of Lahei village about 40-km northeast of Palangka Raya. There are heath and peat swamp forests. The peat layer depth was from less than 1-m (in the heath forest) to about 4-6 m in the peat swamp forest (Haraguchi et al. 2000). We set three plots in 1997 (Miyamoto et al. 2003).

6) Others

1. Vegetation survey plot
   1 x 1 m vegetation survey plot was set in Kalanpangan (2.3 S, 114.0 E), Danau Lais (2.1 S, 114.0), Lahei (1.9 S, 114.1 E) and Sebangau (2.0 19′S, 113 54′E). The relationship between plant communities and soil conditions was evaluated in three forests and a sedge grassland in areas of Lahei and Setia Alam by Dr. Yabe and Shiodera.
2. Research for Acasia Mangium
   We selected sample from open road side in Kalampangan and Hampangen for this research. We studied the relationship between leaf color, growth and soil edaphic condition in Acacia Mangium to identify the suitable habit on the peat swamp soil.

Results

1) Kalamapangan

Simbolon et al. (2004) clarified the recovery process in drained peat swamp there.

2) Sebangau

We conducted re-measurement and calculated forest dynamics parameters about 10 years.

3) UNPAR forest

Shiodera et al. (2012) identified forest recovery after peat fire in un-drained forest. Species diversity and individual number attained the similar level with un-burnt forest after 10 years of disturbance. However, the carbon stock was one-third before peat fire.

4) Bawan village

The comparison of sapling traits between peat swamp and heath forest showed that saplings have very high plasticity and change their characteristics in response to their habitat.

5) Lahei

Haraguchi and Seino conducted re-measurement of peat depth in burnt and deforested area in 2013. The plot in the kerangas forest had burned completely in 2002 and then burned twice in 2004. About 2/3 of the plot 1 has been converted to the karet (Hevea brasiliensis ;Euphorbiaceae) plantation since 2006. Secondary forest with canopy height of ca. 10 m has been revegetated on the remaining part of the plot. After 15 years from peat fire, averaged peat layer thickness became the same level with natural forest. This implies that even after the burned down of above ground vegetation as well as litter layer of the kerangas forest, peat layer remains even if the original peat deposition was shallow before fire.

6) Others

1. Vegetation survey plot

We examined the species composition and edaphic condition of wet grasslands occurring after recent forest burning at three local sites, Kalanpangan, Danau Lais and Lahei around Palangka Raya. Six types of grassland communities were distinguished by TWINSPAN. This community gradient was largest and correlated with soil types from peat to mineral soils, pH from low to high and increasing concentration of minerals (Ca2+, Mg2+, Na+, Cl-, SO42-).

2. Research for Acacia Mangium

The turned leaf color supressed growth and changed their allometry for Acacia Mangium. The factor to decide leaf color seems to be flooding in rainy season.

Discussion

We conducted multi-level researches about human-induced disturbance sites in Central Kalimantan. The survey of secondary-grassland research clarified that ground water level and soil mineral decided the type of secondary-grassland after pear fire. On the other hand, results from research of the burnt forest, we found that the burnt forest recovered for 10 years after peat fire beyond our expectation. Tree density was the highest in the burnt forest. However, in terms of carbon storage, the once-burnt forest was estimated to be only one third of un-burnt forest. The research in Lahei, Haraguchi and Seino (this proceedings) suggested that peat depth will be able to increase after peat fire, if ground water level was kept (no drainage). These results indicated that high water level was the most important factor for forest recovery in peat swamp forest. Peat swamp forest ecosystem is highly vulnerable and hard to recover after disturbance, especially drained situation. The research of Acacia mangium showed that the flooding site was not so suitable for growth of this species. We also found some Hevea brasiliensis (Para rubber tree) which leaves turned yellow similar with Acacia Mangium. Then, their growth seems to be restricted such site. This means that the burnt peat swamp forest is not effective plantation site. If suitable water table is not kept, the forest cannot regenerate for a long time. In current study, we revealed that if burnt forest could avoid peat fire damage for only ten years, they could reforest at some level in our sites. To prevent forest degradation, we need to prevent forest from suffering serious damage by peat fire. Because many uncontrolled sites are found around Palangka Raya, water level control and forest recovery will be desired in the future.

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References

Anderson JAR (1963) The flora of the peat swamp forests of Sarawak and Brunei. Including a catalogue of all recorded species of flowering plants, ferns and fern allies. Gard Bull Singap 29: 131-228.

Haraguchi, A. ,Shimada S. and Takahashi H. (2000) Distribution of Peat and its Chemical Properties around Lahei in the Catchment of the Mangkutup River, Central Kalimantan. TROPICS, 10 (No.2): 265-272.

Miyamoto K, Suzuki E, Kohyama T, Seino T, Mirmanto E and Simbolon H (2003) Habitat differentiation among tree species with small-scale variation of humus depth and topography in a tropical heath forest of Central Kalimantan, Indonesia. Journal of Tropical Ecology 19:43-54

Simbolon, H. (2004). Early process of recovery of peat swamp forest at Kelampangan-Central Kalimantan after forest fires December 1997 and September 2002. Berita Biologi 7: 145-154 (in Indonesian).

Satomi SHIODERA, Tika Dewi Atikah, Joeni Setijo Rahajo, Ismail Apandi, Tatsuyuki Seino, Akira Haraguchi, Afentina S. Hut, Takashi Kohyama (2012), Impact of peat-fire disturbance to forest structure in tropical peat forest in Central Kalimantan, Indonesia, Boreal Forest Research, 2012, 60, 59-62.

Yule CM (2010) Loss of biodiversity and ecosystem functioning in Indo-Malayan peat swamp forests. Biodivers. Conserv. 19: 393-409

Effect of fire on properties of organic matter in tropical soil

Hideki Kuramitz[1)]*, Kazuto Sazawa[1)], Yustiawati[2)], Masaaki Kurasaki[2)], Sulmin Gumiri[3)], Ardianor[3)], Takeshi Saito[4)], Toshiyuki Hosokawa[5)], M. Suhaemi Syawal[6)], and Shunitz Tanaka[2)]

[1)] Graduate School of Science and Engineering for Research, University of Toyama, Toyama, Japan
[2)] Graduate School of Environmental Science, Hokkaido University, Sapporo, Japan
[3)] Faculty of Agriculture, University of Palangka Raya, Palangka Raya, Indonessia
[4)] Graduate School of Health Science, Hokkaido University, Sapporo, Japan
[5)] Center for Research and Development in Higher Education, Hokkaido University, Sapporo, Japan
[6)] Research Center for Limnology of LIPI, Bogor, Indonesia

* E-mail address: kuramitz@sci.u-toyama.ac.jp

We have investigated that the effects of peatland fire on the organic matter including humic substances in water and soil to further understand the impact of peat land fire in Central Kalimantan. Furthermore, the toxicity of dissolved humic substances and its removal for drinking water have also been studied. In this manuscript, we escrobed on the summary of our studies and elaborate mainly on three topics as follows. 1) Effect of wild peat fire on the properties of soil organic matter: The dissolved organic matter (DOC) concentrations in soil collected from burned area are found to be lower than that of unburned soil. One possible reason for this phenomenon could be denaturation of soil organic matter (SOM) from the heat caused by fire. Therefore, the changes in concentrations and fractionations of DOC in the peat soil by thermally treating at various heating temperature were investigated in laboratory setup. As the result, we found that the DOC especially hydrophilic fraction increased drastically from the heat treatment around the ignition temperature of this peat soil. The results from the investigations conducted both in field and laboratory experiments reveal that the denaturation of SOM caused by the heat from the fire accelerates the exodus of organic carbon at peat land, which has a huge accumulation of carbon storage. 2) Evaluation of forest fire severity and effect on soil organic matter based on the CIE Lab color reading system: The purpose of this study is to evaluate the effect forest fires have on the soil color. It was found that the Δa^* and Δb^* values drastically decrease when samples were heated over the temperature range from 200 to 250 °C and show a good linear negative correlation with the atomic ratios of H/C and O/C. The results obtained from this study indicate that the proposed method is able to evaluate the dehydration and decarboxylation of SOM caused by forest fires. 3) Removal of DOC for drinking water: The prominent feature in the tap water of Parangka Raya is a high concentration of DOC. We carried out investigation for removal of humic substances from water through coagulation method using polyaluminum chloride (PAC) with CaCO3 as neutralizer and coagulant aid. Since CaCO3 behaves as a coagulant reagent, the sedimentation velocity was significantly high and the sludge volume was reduced about half compared with existent method using NaOH as neutralizer. The demonstration was performed by using Sebangau River water which consists of 33.4 mg/L of DOC. The residual DOC concentration of 4.5 mg/L was successfully proved by this method.

Keywords: soil organic matter, CIE Lab color reading system, Removal of humic substances.

1) Effect of wild peat fire on the properties of soil organic matter

In this research area, the major component of dissolved organic matter (DOM) in river and canal water is terrestrial humic substances. Namely, this indicates that the changes in the existing components of soil are strongly influenced by water quality. Therefore, it is necessary to conduct a qualitative and quantitative assessment to further understand the changes in soil organic matter (SOM) from the impact of peat land fire. Previous reports have been indicated that lignin and hemicelluloses started to degrade at 130-190 ºC, whereas carbonization process (dehydration and decarboxylation) starts above 200 ºC (Chandler et al., 1983; Freitas et al., 1999). From this fact, we can assume soil and river ecosystem is strongly influenced by the peat land fire. However, the current information available regarding the quantitative and qualiative changes of SOM in tropical peat is still limitted.

The physicochemical properties of peat soil collected from unburned and burned area near Palangka Raya city were compared. In the case of peat soil collected from surface layer (0-20 cm), an increment in pH and particle density was observed. The pH values of unburned and burned soil were 3.1-3.4 and 4.7-5.8, respectively. After the burning, the particle density increased from 1.05-1.22 to 1.39-1.58. On the other hand, such differences between burned and unburned were not clearly seen in the soil collected from subsurface (30-50 cm) layer.

Thermogravimetry-Differential Thermal Analysis (TG-DTA) curves for the peat soil collected from the subsurface in the unburned area are shown in Figure 1. The sample was heated from 20 to 500 ºC at a rate of 3 ºC min-1. The TG curve shows that this peat soil is mostly composed of organic matter (approximately 98 wt%). From the obtained DTA curve, the ignition temperature (Tv), combustible gas release (peak A), and the combustion of carbide (peak B) were determined to be at 186 ºC (Tv), 306, and 425 ºC, respectively. The combustion characteristics of the soil which was collected from the burned area were also evaluated. The height for peak A and peak B in the DTA curve obtained from the surface layer of soil collected in burned area were lower than that of unburned soil. This means the surface layer of soil contains lesser organic components in burned area. In the case of subsurface layer of burned soil, the peak A value drastically decreased, whereas the peak B value was 56% higher than the unburned soil. Moreover, the ignition temperature increased up to 220 ºC. The results of the TG-DTA observations suggest that the production of charred material occurred in the burned soil at the subsurface layer. Charred material is highly resistant to heat and biological degradation, thus, the transformation of SOM in burned soil has a potential to affect the soil and river ecosystem.

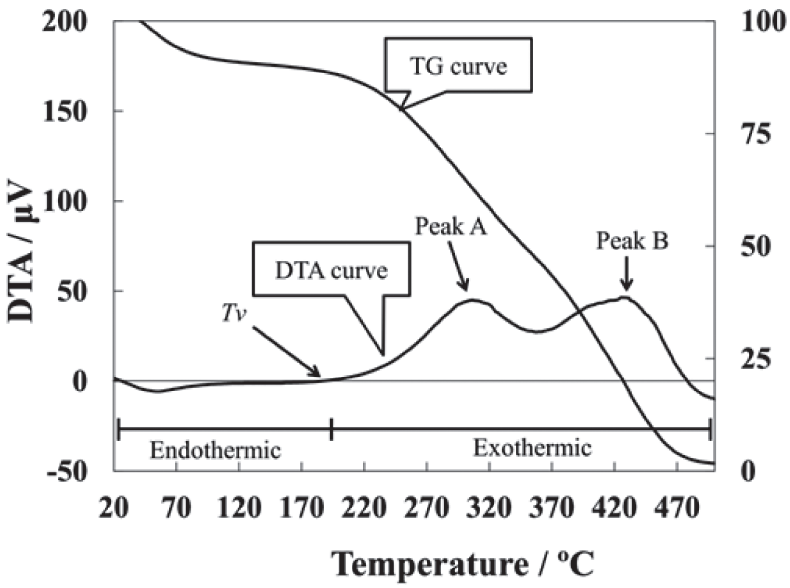


Fig. 1 TG-DTA curves of the Indonesian peat soil collected from the subsurface (30-50 cm) in the unburned area. Tv: ignition temperature of the volatile matter; peak A: combustible gas release; peak B: combustion of carbide (Sazawa et al., 2013).

In addition, the decreasing of the atomic ratios for H/C and O/C which shows carbonization of SOM was observed from the elemental analysis of the subsurface soil collected from the burned area. This finding supports the result obtained from the TG-DTA experiments. The elemental analysis was performed to evaluate the heating temperature of the subsurface soil in burned area by thermally treating the samples at different temperatures. Results indicated that the atomic ratios of H/C and O/C for the soil samples collected from subsurface layer in burned area showed similar value for the heated peat soil samples at a slightly lower ignition temperature. It has been commonly reported that forest fire mainly affects only the soil surface layer. In fact, some researchers have even concluded that the heat from the fire is not transferable to a depth of 20-30 cm from the surface of the soil, even if surface temperature exceeds 500-700 ºC (Neary et al., 199; DeBano, 2000). The findings from this investigation suggest that subsurface layer SOM was carbonized from the heating by fire and this is said to be a key characteristic for tropical peat soil damaged by the forest fire. The most obvious difference observed in the aftermath of forest fire between peat land and forest soil is that heat is much easily transferred to the subsurface level of peat land soil than the forest soil.

The DOC in soil is strongly linked to the storage of carbon in catchment soil. The DOC concentrations and fractionations of soil water-extracted solution for the Indonesian peat soil samples collected in Oct. 2010 from unburned (UB 1, 2, 3) and burned (B 1, 2, 3) areas at the subsurface layer are shown in Figure 2 (a). The DOC components of water-extracted soil were fractionated by using DAX-8 resin. In this study, the DOC fractions of soil extracted by water were divided into three groups based on the affinity of DAX-8 resin: Hydrophilic (Hp: fatty acids, sugar acids, hydroxyl acids, polysaccharides etc.) and hydrophobic bases (HoB: aromatic amines) fraction (Hp + HoB) is not absorbed, hydrophobic acid (HoA: humic and fulvic acids) fraction and hydrophobic neutral (HoN: large cellulose polymers, hydrocarbons, carbonyl compounds etc.) fraction is absorbed to DAX-8. HoA fraction can be extracted with alkali solution from the DAX-8, while HoN cannot be extracted. The DOC concentrations in soil collected from burned area are found to be lower than that of unburned soil. The each fractions of DOC were as follows: Hp + HoB = 16-31%, HoA = 48-63%, HoN = 12-28% in unburned soil and Hp + HoB = 25-30%, HoA = 25-53%, HoN = 19-45% in burned soil. These data concludes that the fire contributes towards reduction of the DOC especially hydrophilic fractions. Figure 2 (b) shows the experimental results

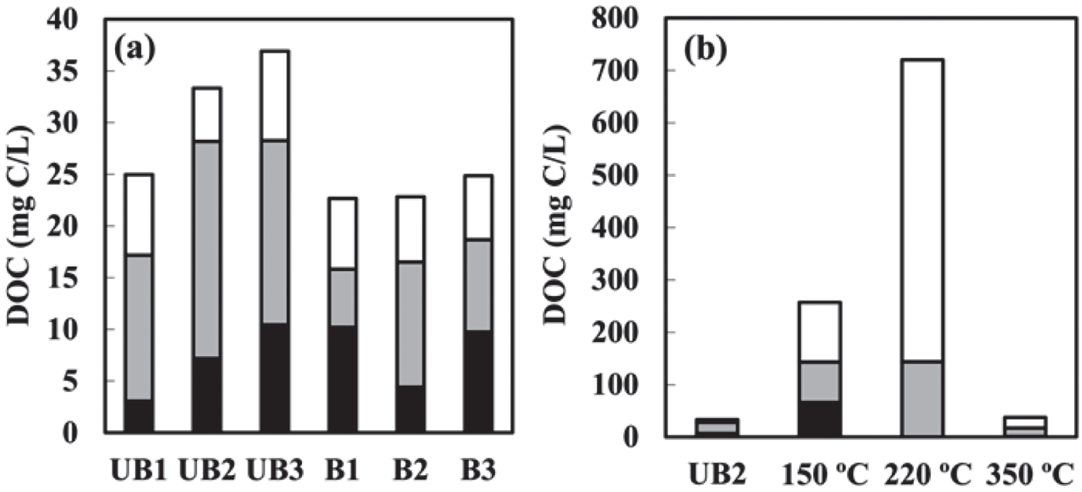


Fig. 2 The DOC concentrations and fractionations of soil water-extracted solution for the Indonesian peat soil samples collected from unburned (UB 1, 2, 3) and burned (B 1, 2, 3) areas at the subsurface layer (30-50 cm) and (b) thermally treated Indonesian peat soil samples (150, 220 and 350 ºC for 30 min). White bar = Hydrophilic and Hydrophobic bases fraction (Hp + HoB), Gray bar = Hydrophobic acids fraction (HoA), Black bar = Hydrophobic neutrals fraction (HoN).

obtained by thermal treatment at 150, 220 and 350 ºC for 30 min. The concentration of DOC especially hydrophilic fraction increased drastically from the heat treatment at 150 and 220 ºC, which is around the ignition temperature of peat soil. In this case, it was observed by means of the size exclusion chromatography and the spectrophotometric analysis that the molecular weights of DOC components extracted from the soil showed lower than that before heating.

2) Evaluation of forest fire severity and effect on soil organic matter based on the CIE Lab color reading system

The evaluation of forest fire severity and effect on soil is very important to discuss the damage to the environment. The purpose of this study is to evaluate the effect of forest fire on the changes in soil color using the CIE Lab system. The color changes of four kinds of soil samples caused by heating at different temperature were investigated. As shown in Fig. 3, it was found that the Δa* and Δb* values drastically decrease by heating at a temperature range from 200 to 250 °C, that is above the ignition temperature of volatile matters. The Δa* and Δb* values showed a good liner negative correlation with atomic ratios of H/C and O/C. These results obtained from this study indicate that the proposed method is able to evaluate the dehydration and decarboxylation of soil caused by forest fire. The findings from this study suggest that the proposed method can be used as a rapid, user-friendly and in situ analysis to evaluate the impact of forest fire on soil.

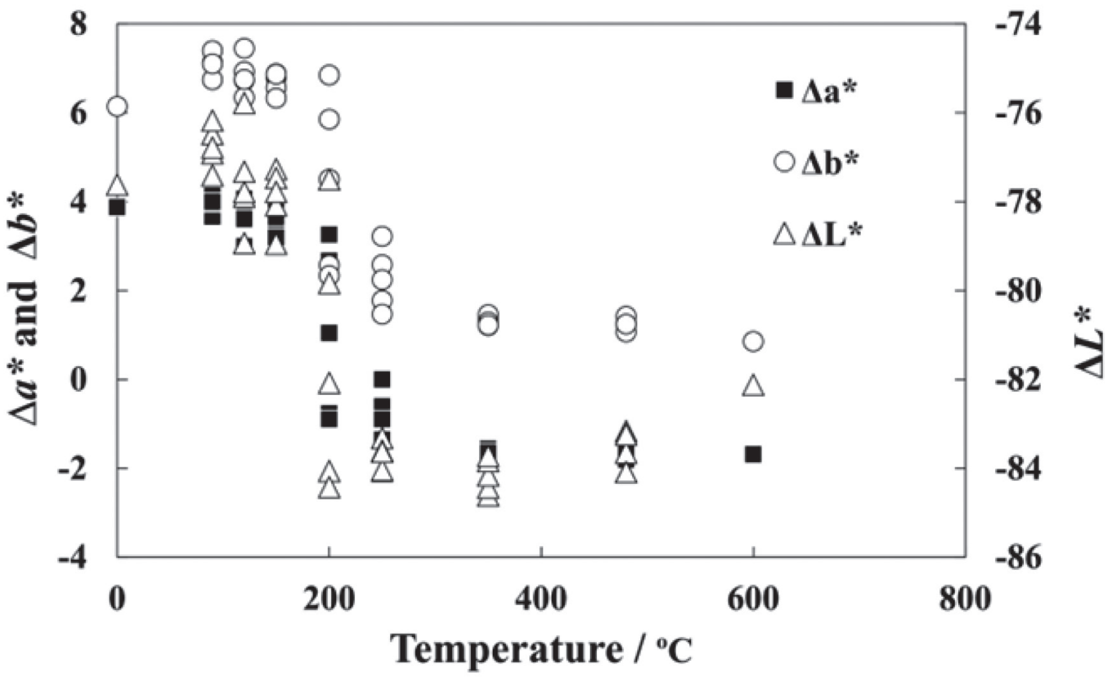


Fig. 3 Relationship between heating temperature and the change of Δa* (○), Δb* (□) and ΔL*(■) values of thermally treated Indonesia's peat soil samples at different temperature.

3) Removal of DOC for drinking water

Samples of tap water were collected from Bogor, Cibinong, Jakarta and Parangka Raya and were tested for water quality. Table 1 shows the concentrations of nitrate-nitrogen (NO3-N), ammonium-nitrogen (NH4-N) and DOC found in the tap water and the respective fluorescence properties. As a reference, the parameters for the quality of water taken from the rivers flowing through these cities are presented in Table 1. The prominent feature in the tap water sample from Parangka Raya is high concentration of NH4-N and DOC.

There have been reports that have even linked dissolved humic substances (DHS) to endemic diseases. For example, the daily intake of high concentration of humic acids (HA; approximately 200 mg/L) contained in artesian well water is thought to be the root cause of Blackfoot disease which prevails in southwest of Taiwan (Cheng et al., 1999). Taking this into consideration, we carried out further investigation by removing humic substances from water through coagulation method using polyaluminum chloride (PAC) with CaCO3 as neutralizer and coagulant aid. The removal of HA was achieved for 96.6 and 91.6 % which calculated from absorbance at 260 nm and concentration of DOC when CaCO3 was used as alkaline chemical with PAC. Since CaCO3 behaves as a coagulant reagent, the sedimentation velocity was significantly high and the sludge volume (SV) was reduced about half compared with existent method using NaOH as neutralizer. It can be said that CaCO3 is efficient because it is able to function both as alkaline chemical and coagulant aid. The demonstration was performed by using Sebangau River water which consists of 33.4 mg/L of DOC. The lowest residual DOC concentration of 4.5 mg/L, which is lower than the water quality standards for drinking water in Indonesia, was successfully proved by this proposed treatment method.

Table 1 The parameters for water quality and the relative fluorescence intensity of protein-like substances (Peak T) and humic-like substances (Peak C) in river and tap water collected from Bogor, Cibinong, Jakarta and Palangka Raya, Indonesia N.D. = no detection.

		NO_3-N	NH_4-N	DOC	Peak T	Peak C
			(ppm)		(QSU)	
Bogor	River water	9.9	0.04	2.9	180.9	23.4
	Tap water	3.0	N.D.	2.7	294.8	8.2
Cibinong	River water	11.8	0.06	2.0	131.7	20.3
	Tap water	5.0	0.05	4.4	336.2	5.4
Jakarta	River water	16.7	> 0.6	5.1	374.7	52.6
	Tap water	3.2	0.04	3.5	340.1	9.7
Palangka Raya	Tap water	N.D.	> 0.6	11.6	190.1	134.5

References

Chandler C, Cheney P, Thomas P, Trabaud L, Williams D (1983) Forest fire behavior and e□ects. In: Fire in forestry Wiley, New York

Cheng ML, Ho HY, Chiu DTY, Lu FJ (1999) Humic acid-mediated oxidative damages to human erythrocytes: a possible mechanism leading to anemia in blackfoot disease. Free Radic. Bio. Med. 27:470-477. doi:10.1016/S0891-5849(99)00072-6

DeBano LF (2000) The role of fire and soil heating on water repellence in wildland environments: a review. J Hydrol 231:195–206. doi:10.1016/S0022-1694(00)00194-3

Freitas JCC, Bonagamba TJ, Emmerich FG (1999) 13C High-Resolution Solid-State NMR Study of Peat Carbonization, Energy Fuels 13:53–59. doi:10.1021/ef980075c

Neary DG, Klopatek CC, DeBano LF, Fgolliott PF (1999) Fire effects on belowground sustainability: a review and synthesis. For Ecol Manage 122:51–71. doi:10.1016/S0378-1127(99)00032-8

Sazawa K,Wakimoto T, Hata N, Taguchi S, Tanaka S, Tafu M, Kuramitz H (2013) The evaluation of forest fire severity and effect on soil organic matter based on the L*, a*, b* color reading system. Analytical Methods 5:2660–2665. doi: 10.1039/c3ay26251k

Enzymatic saccharification of Indonesian agroforestrial waste by using amphipathic lignin derivatives

Yasumitsu Uraki[1)*], Ina Winarni[2)], Teuku Beuna Bardant[3)], Yanni Sudiyani[3)], Yutaka Tamai[1)] and Keiichi Koda[1)]

[1)] Research Faculty of Agriculture, Hokkaido University, Sapporo 060-8589, Japan
[2)] Forestry Research and Development Agency (FORDA), Bogor 16610, Indonesia
[3)] Research Center for Chemistry, Indonesian Institute of Science (KIM-LIPI), Serpong, Tangerang 14513, Indonesia

[*] E-mail address: uraki@for.agr.hokudai.ac.jp

To reduce use of fossil resources and suppress emission of carbon dioxide by using biomass, utilization of agroforestrial wastes, especially oil palm wastes (empty fruit bunch (EFB) and trunk) and sago palm waste in Indonesia, is one of important subjects. In this study, we investigate to improve saccharification efficiency of such agroforestrial wastes by using amphipathic lignin derivatives as a cellulolytic enzyme-aid in order to produce glucose as a feedstock for bioethanol and other chemicals produced by fermentation. As a result, the saccharification efficiency of EFB was dramatically improved by the addition of the lignin derivatives. In the case of saccharification of sago waste, the saccharification efficiency was also improved, and the enzyme could be used repeatedly by the assisting action of the lignin derivatives.

Keywords: oil palm waste, sago waste, enzymatic saccharification, amphipathic lignin derivatives.

Introduction

Utilization of agroforestrial wastes have been drawn much attentions in order to reduce use of fossil resources and emission of carbon dioxide, and to create sustainable society with resource recycling system. In Indonesia agroforestrial wastes, oil palm wastes, such as EFB and trunk, and sago palm waste are very promising and alternative biomass to fossile resources, because they are considered as intensified feedstock due to the fact that they are discharged in much quantity from the factories of oil and starch extractions, respectively. When glucose is easily obtained from the waste biomass or lignocellulosics, bioethanol as an alternative liquid fuel and other organic compounds as chemicals can be produced by fermentation. Therefore, saccharification of cellulose component in the waste is a key process for utilization of unused biomass. Enzymatic saccharification of such lignocelluloses with cellulase is assumed to be environmentally friendly, but this process is not economically feasible because the enzyme is more expensive than amylase for starch (Himmel et al. 1997). To overcome the obstacle, the enzyme can be used repeatedly or its hydrolysis activity should be maintained for a long period. From this point of view, we developed cellulase-aid agents from lignin. Here, we report their performance for the saccharification of Indonesian agroforestrial waste.

Methods

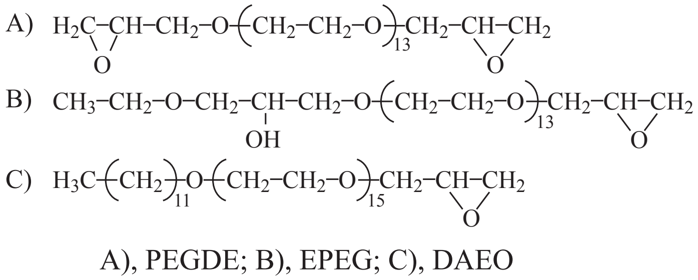
Materials

EFB was collected in the plantation of PT Perkebunan Nusantara VIII (Pandeglan, Indonesia), and was cut into 3-5 cm in length. The EFB pieces were subjected to kraft pulping under the following conditions: active alkali, 30%; sulfidity, 30%; liquor to wood ratio (LW), 4 or 5.Time to 165 oC was 90 min, and then the temperature was kept for 90 min. After the cooking, the pulp as a residue was washed with water until pH of washings was neutral. This pulp was disintegrated and beaten by disk refinery. Pulp-1 with Klason lignin (KL) content of 9.96% was obtained by the cooking at LW of 5, pulp-2 with KL of 12.4% was at LW of 4 (Bardant et al. 2010).

Fibrous sago waste was obtained from a local sago starch factory in Cimahpar, Bogor, Indonesia. The fibrous sago waste left on the bare ground was washed with water to remove soil, and dried under sunshine for 2-3 days. This waste was then ground and collected through 35 mesh screen. Firstly, fibrous sago waste was hydrolyzed with 4% HCl at 80°C for 60 min as a pretreatment to remove residual starch. This reaction suspension was filtered, and the residue was washed with distilled water. The filtration residue was then rinsed with acetone, and dried. This pretreated sago waste was subjected to the soda-anthraquinone pulping at two alkaline concentrations as follows. The fibrous sago waste (200 g) was pulped, using 30 g or 40 g NaOH in 487 mL of distilled water together with 1 g of anthraquinone. The mixture was heated from room temperature to the cooking temperature (165°C) for 120 min, and the cooking temperature was maintained for 90 min. The crude pulp was washed with 1% NaOH solution and distilled water, successively, and filtered by pressing to reduce its moisture content down to 70%. The pulp was lyophilized to yield a dry pulp. The KL contents of the sago pulps, pulp-3 and pulp-4, prepared each with 30 g and 40 g NaOH, were 10.2% and 1.8%, respectively (Winarni et. al. 2014).

Amphipathic lignin derivatives were prepared by the reaction of hardwood acetic acid lignin (AL); (Uraki et al. 1995) or soda-sago lignin (SSL); (Winarni et al. 2014), which was isolated from the black liquor of soda-pulping of sago waste mentioned above, with epoxylated poly (ethylene glycol) analogues, poly(ethylene glycol) diglycidyl ether (PEGDE), ethoxy-(2-hydroxy)-propoxy-poly(ethylene glycol) glycidyl ether (EPEG), and dodecyloxy-poly(ethylene glycol) glycidyl ether (DAEO), as shown in Fig. 1(Homma et. al. 2010).

Fig.1. Chemical structures of epoxylated PEG analogues.



A), PEGDE; B), EPEG; C), DAEO

Enzymatic Saccharification of EFB kraft pulp and sago soda pulp

Meicelase (Meiji Seika Co. Ltd. Japan; powder form) and Genencor GC220 (Genencor International Inc., USA; Lot # 4901121718; solution) were used as a cellulase commercially available. Cellulolytic activities of both enzymes as received were 40 filter paper unit (FPU)/g and 64.9 FPU /mL, respectively, where FPU was measured according to the method in NREL technical report, (NREL/TP-510-42628). Each amphipathic lignin derivative (10% of substrate on dry weight basis) was dissolved in50 mL of 50 mM citrate buffer (pH 4.8). The cellulase at a dosage of 10 or 20 FPU/g of substrate was added to the solution, and the mixture was stirred for 1 h. Finally, 0.5 g of unbleached pulp was added to the solution, and the suspension was gently shaken at 50°C for 48 h. In the case of saccharification of EFB pulp, the pulp consistency in the media was 7.5 or 45 g/L. After saccharification, the suspension was filtered through a G4 glass filter. The precipitate was washed three times with the buffer solution, and weighed after complete drying at 105°C. The saccharification efficiency (SE) was calculated, by using the following equation:

$$SE (\%) = (WS – WR) \times 100 / WS \quad (1)$$

where, WS is the initial weight of substrate (g), and WR is the weight of residue (g) after saccharification.

In the case of saccharification of sago pulps, the filtrate was subjected to ultrafiltration with a polysulfone membrane (cut-off molecular mass, 1000 Da). The residual enzyme solution (ca. 10 mL) as a concentrate of unfiltered fraction was diluted with 50 mL of the buffer solution, and ultrafiltered again up to 10 mL, and this process was repeated three times to recover and purify the used enzyme. The recovered enzyme solution was added to a new saccharification media, in which the pulp as the substrate was suspended, and the saccharification was carried out under the same conditions as the first conditions. This saccharification-ultrafiltration process was repeated 4times. SE measurement was conducted at each process.

Results and Discussion

Enzymatic saccharification of EFB kraft pulps
EFB kraft pulps, pulp-1 and pulp-2, were subjected to enzymatic saccharification with meicelase as a commercially available cellulase. In the absence of cellulolytic enzyme as a control experiment, each saccharification efficiency (SE) for pulp-1 and -2 were 51.5%

Table 1. Enzymatic saccharification of EFB kraft pulp

Substrate	Substrate consistency (g/L)	PEGDE-AL	Saccarification efficiency (%)
Pulp-1	7.5	X	51.5 (57.2)
(KL, 9.96%)	7.5	O	84.4 (94.7)
Pulp-1	45	X	23.5 (26.1)
(KL, 9.96%)	45	O	50.0 (55.5)
Pulp-2	7.5	X	49.5 (56.5)
(KL, 12.4%)	7.5	O	71.4 (81.5)

Meicelase with 20 FPU / g of substrate was used in this saccharification. X, no addition of PEGDE-AL. O, 10% PEGDE-AL based on substrate weight was added to the reactor. Parenthesis indicate saccharification efficiency based on holocellulose.

and 49.5% at a pulp consistency of 7.5 g/L, respectively, while the corresponding SEs were dramatically improved to 84.4% and 71.4%, respectively, by the addition of amphipathic lignin derivative, PEGDE-AL, prepared from birch ligin. The SE of 84.4% corresponded to 94.7% of saccharification yield based on holocellulose or total polysaccharides in the pulp.Thus, the quantitative saccharification was brought about by the lignin derivative.

Enzymatic saccharification of sago pulps

Sago waste pulp was prepared by soda-anthraquinone pulping after removing residual starch by mild acid treatment. Three types of amphipathic lignin derivatives were also prepared from the black liquor of sago waste pulping by isolation process followed by the derivatization reactions with epoxylated polyethylene glycol analogues. The saccharification of the pulp was repeated 4 times by using Genecor GC220, which was supplied to the following saccharification after the purification of the used enzyme by ultrafiltration, together with amphipathic.

In the saccharification of sago pulps without additive (control experiment), the SEs for pulp-3 with high lignin content and pulp-4 with low lignin content were remarkably decreased from 78% and 88% at the first saccharification to 3% and 12% at the forth saccharifrication, respectively (Fig. 2). On the other hand, the initial SEs were significantly improved by the addition of SSL-based amphipathic derivatives, DAEO-SSL in particular. Furthermore, the high initial SEs were kept at higher levels (about 70% for pulp-3 and 80% for pulp-4) until the forth saccharification by SSL-based derivatives (Fig. 3). Thus, SSL was also found to act as a cellulase-aid agent for improvement and maintainning of SE.

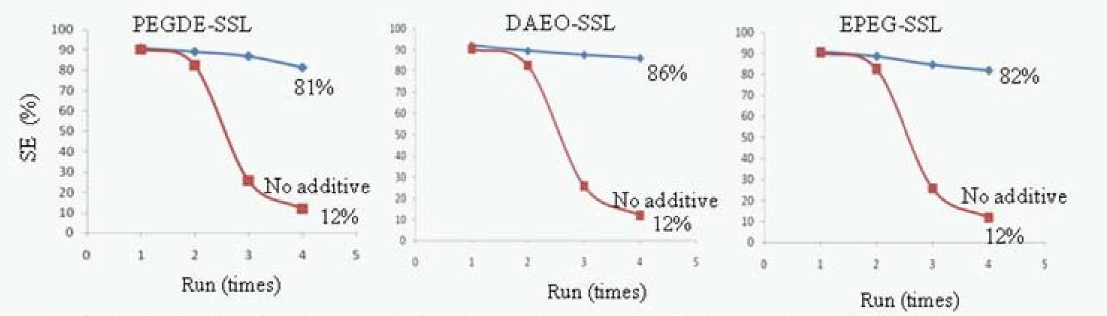


Fig. 2. Saccharification efficiency (SE) of sago pulp-4 with low lignin content (1.8%) in the presence of SSL-based amphipathic derivatives.

Fig. 3. Saccharification efficiency (SE) of sago pulp-4 with high lignin content (10.2%) in the presence of SSL-based amphipathic derivatives.

Conclusions

In this study, we attempted to improve enzymatic saccharification of Indonesian agroforestrial waste, EFB of oil palm and fibrous sago waste. EFB kraft pulps was saccharified very effectively by the addition of amphipathic lignin derivative prepared from hardwood (birch) acetic acid lignin (AL). In addition, sago soda-pulps were also effectively saccharified in the presence of SSL-based amphipathic deivatives. These results suggests that amphipathic lignin derivatives were useful materials to improve the saccharification of agroforestrial wastes, which we term "cellulased-aid agent", and such the lignin derivatives can be prepared from any lignin (Winarni et. al. 2013).

References

Bardant, T. B. Oikawa, C. Nojiri, M. Koda, K. Sudiyani, Y. Yamada, T. and Uraki, Y. (2010). Improvement of saccharification of empty fruit bunch and Japanese cedar pulps with an amphiphilic lignin derivative, Mokuzai Gakkaishi, 56 (6), 420-426.

Himmel, M. E. Adney, W. S. Baker, J. O. Elander, R. McMillan, J. D. Nieves, R. A. Sheehan, J. Thomas, S. R. Vinzant, T. B. and Zhang, M. (1997). "Advanced bioethanol production technologies: A prespective," In :Fuels and Chemicals from Biomass, J. Woodward, and B. Saha (eds.), Washington, D.C. pp. 2-45.

Homma, H. Kubo, S. Yamada, T. Koda, K. Matsushita, Y. and Uraki, Y. (2010). Conversion of Technical Lignins to Amphiphilic Derivatives with High Surface Activity. Journal of Wood Chemistry and Technology, 30(2), 164-174.

Uraki, Y. Kubo, S. Nigo, N. Sano, Y. and Sasaya, T. (1995). Preparation of carbon fibers from organosolv lignin obtained by aqueous acetic acid pulping. Holzforschung, 49(4), 343-350.

Winarni, I. Oikawa, C. Yamada, T. Igarashi, K. Koda K. and Uraki, Y. (2013). Improvement of enzymatic saccharification of unbleached cedar pulp with amphipathic lignin derivatives. BioResorces, 8(2), 2195-2208.

Winarni, I. Koda, K. Waluyo, T. K. and Uraki, Y. (2014). Enzymatic Saccharification of Soda Pulp from Sago Starch Waste Using Sago Lignin-Based Amphipathic Derivatives. Journal of Wood Chemistry and Technology, in press.

A Model On Ground Water Level Prediction

Nobuyuki Tsuji

The Center for Sustainable Science, Hokkaido University
Kita 9, Nishi 8, Kita-ku, Sapporo, 060-0809, Japan

E-mail address: n-tsuji@census.hokudai.ac.jp

Groundwater level is very important parameter in peat land management, especially, peat fire management. I tried to establish a model on ground water level prediction by Kalman filter theory, which is frequently used in system engineering field. I made a very simple model, but got good results.

Keywords: Kalman filter, prediction

Introduction

Ground water level in peatland is very important, because it effects strongly on CO2 emission from peat, subsidence, fire occurrence, oil palm production, and so on. It may be practically useful to predict ground water level at half month later, for example, during especially dry season. Because, people living there could prepare a risk for wild fire. Hokkaido University has many observing stations with cellular phone data transmitting system. These stations are giving us real-time ground water level data.

There are many models for describing a ground water dynamics; tank model, and nearest neighbor method (Kudo & Nakatsugawa, 2012), and so on. I employ Kalman filter model here, because it is very simple; this theory does not require the detailed ground water dynamics such as tank model, and accepts disturbance and observation noises. Kalman filter was proposed by R. Kalman (1960), and this theory has been widely used in many fields. In this theory, system and observation dynamics are generally assumed as follows:

$$x(k+1) = A(k)x(k) + \xi(k)$$
$$y(k) = H(k)x(k) + \eta(k)$$

where, $x(k)$ is a state variable at day k, $y(k)$ an observation variable, $A(k)$ transition matrix, $H(k)$ observation matrix, $\xi(k)$ disturbance noise (white Gaussian $N(0,\ W(k))$), $\eta(k)$ observation noise (white Gaussian, $N(0,\ V(k))$).This theory gives as follows:

$$\hat{x}(k|k-1) = A(k)\hat{x}(k-1|k-1)$$
$$\hat{x}(k|k) = \hat{x}(k|k-1) + K(k)\big(y(k) - H(k)\hat{x}(k|k-1)\big)$$
$$C(k|k) = C(k|k-1) - K(k)H(k)C(k|k-1)$$
$$C(k|k-1) = A(k)C(k-1|k-1)A^T + W(k)$$
$$K(k) = C(k|k-1)H(k)^T\big(H(k)C(k|k-1)H(k)^T + V(k)\big)^{-1}$$

where, $\hat{x}(k|k)$ is the value at day k estimated by based on information at day k, $\hat{x}(k|k-1)$ the value at day k predicted by based on information at day k-1, C covariance matrix of $\hat{x}$. And, "T" means transpose matrix, "-1" inverse matrix.

Model

Nakamura & Hatazaki (1975) made a model for predicting electric power amount consuming in Kyusyu Island, Japan. I applied their model to ground water level prediction.I set the state variable as follows:

$$x(k) = g(k) - g(k-L)$$

where, *g(k)* and *g(k-L)* are observed ground water level at day k and k-L, respectively (refer to Fig. 1). And, I assumed the system and observation equations as follows:

$$x(k+1) = x(k) + \xi(k) \quad (1)$$
$$y(k) = x(k) + \eta(k) \quad (2)$$

that is, the difference between day k-Land kis assumedto beconstantas the first step. Then,

$$\hat{x}(k+1|k) = \big(1 - K(k)\big)\hat{x}(k|k-1) + K(k)y(k)$$
$$\hat{C}(k+1|k) = \big(1 - K(k)\big)\hat{C}(k|k-1) + W(k)$$
$$K(k) = \frac{\hat{C}(k|k-1)}{\hat{C}(k|k-1) + V(k)}$$
$$\hat{x}(k+1|k) = \big(1 - K(k)\big)\hat{x}(k|k-1) + K(k)y(k)$$
$$\hat{C}(k+1|k) = \big(1 - K(k)\big)C(k|k-1) + W(k)$$
$$K(k) = \frac{\hat{C}(k|k-1)}{\hat{C}(k|k-1) + V(k)}$$

W(k) and *V(k)* are assumed variances of $x(i)$, and $y(i)$ during $i = k$-T and k, respectively.Where T is an arbitrary constant.

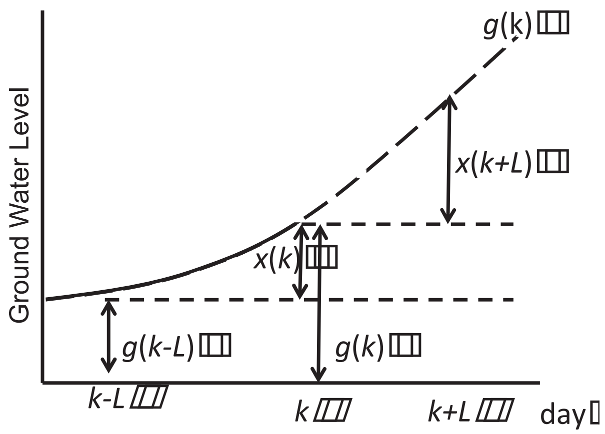


Fig.1 the definition of state variable.

Results and discussion

I try to get the value $\hat{x}(k+L|k)$, that is, to predict the L days ahead from day k. When I get the value $\hat{x}(k|k)$, the value $\hat{x}(k+L|k)$ is

$$\hat{x}(k+L|k) = \hat{x}(k|k).$$

I show the result where L=1, 7, and 15 (Fig. 2). It is natural that prediction accuracy is worse as time span is longer.

Let us consider the case L=15. This model can follow the tendency of ground water level changing, but this may be not accuracy. Because:

1) The assumption, the means of disturbance and observation noise equal to 0, is not satisfied.
2) I assumed that the difference of ground water level between two days (refer to Eq.(1)) is constant. This assumption may be simple too much.
3) I did not consider precipitation in my model, that is, rain is treated as noise. It is natural that precipitation has large effect to ground water level.

I will improve the first step model with considering the above points.

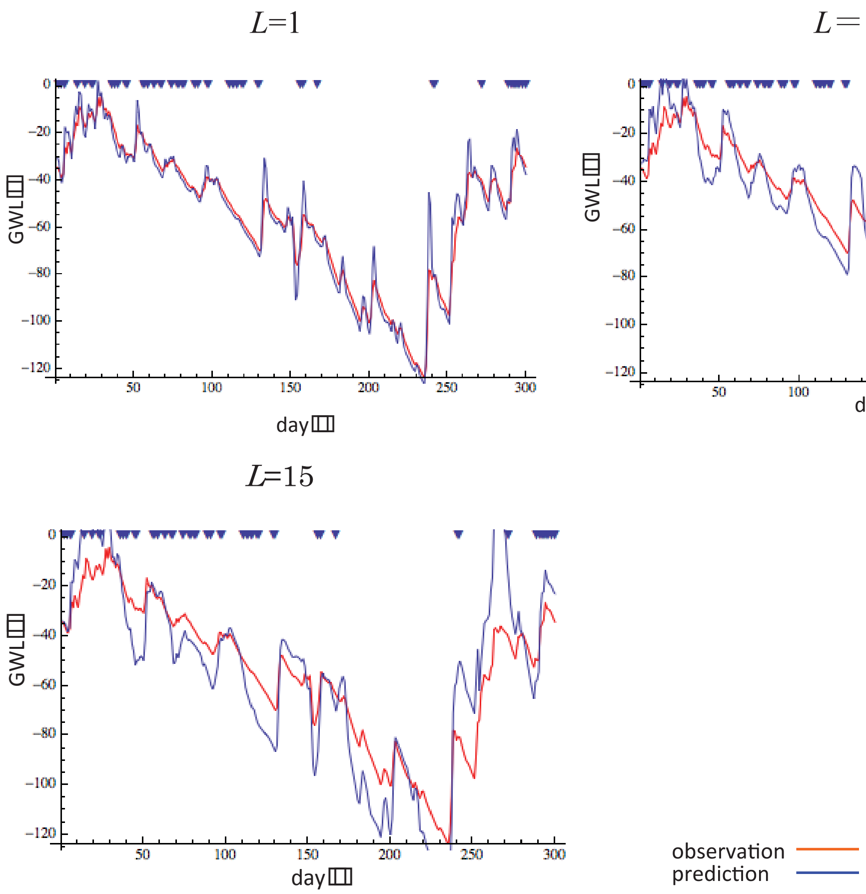


Fig.2. Numerical results. L=1, L=7, and L=15 are 1day, 7days, and 15 days ahead, respectively. "▼"at the top of each graph means rain occurrence.

Acknowledgement

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References

Kudo, S. and Nakatsugawa M. (2012) Research on water level forecasting based on factors affecting water level variation for the Kahayan river in Indonesia, J. of Hydroscience and Hydarulic Eng., vol. 56. (in Japanese with English summary)

Kalman, R.E. (1960) A new approach to linear filtering and prediction problems, Trans.

JICA new project on REDD+ (IJ-REDD+) in Indonesia

Shigeru Takahara
Indonesia-Japan Project for Development of REDD+ Implementation Mechanism (IJ-REDD+), Ministry of Forestry Indonesia - JICA

E-mail address: shige.takahara@gmail.com

A JICA new project, Indonesia-Japan Project for Development of REDD+ Implementation Mechanism (IJ-REDD+) was started from June 2013 as a 3 years technical cooperation between Ministry of Forestry Indonesia for the purpose of developing provincial REDD+ implementation mechanism, aiming to integrate it into national REDD+ mechanism. IJ-REDD+ activities in Central Kalimantan support development of sub-national MRV in collaboration with JICA-JST Project on Wild Fire and Carbon Management in Peat-Forest.

Keywords: REDD+, forestry, JICA

Introduction

The area of tropical forests in Indonesia is the third largest in the world providing rich biodiversity and ecosystem services. JICA (Japan International Cooperation Agency) has a long history of cooperation in Indonesia in the field of forest management and biodiversity conservation.

Recently, forests and peat land in tropical regions draw global attention as one of major sources of GHG emission. Reducing emission from deforestation and forest degradation (REDD+) has emerged as a potential mechanism for tackling this issue and Indonesia is recognized as one of the leading countries for establishing REDD+. JICA's cooperation past and on-going is considered to contribute establishing mechanism of REDD+ in various aspects from central level to field level, from policy issues to technological issues including MRV or safeguards related to community involvement and biodiversity.

In February 2013, JICA and Ministry of Forestry Indonesia agreed to implement a new technical cooperation, "Indonesia-Japan Project for Development of REDD+ Implementation Mechanism (IJ-REDD+)" with the purpose of developing provincial REDD+ implementation mechanism, aiming to integrate it into national REDD+ mechanism.

JICA Forestry Cooperation and REDD+

JICA`s technical cooperation projects in forestry sector in Indonesia started in 1970s. Since then, more than 20 projects have been conducted, including on-going projects, in collaboration with Ministry of Forestry and other organizations. Aims of the projects are varying from transferring of cutting edge technology such as PALSAR satellite image analysis of different vegetation in Indonesia, to biodiversity conservation of national parks or important ecosystem such as mangrove, and collaboration with communities in forest management or forest fire prevention.

Among others, JICA-JST Project on Wild Fire and Carbon Management in Peat-Forest (hereinafter referred as JICA-JST project) are important in the context of mitigating climate change, considering significant GHG emission in Indonesia originated from peat land.
Also Japan`s commitment for addressing global warming issues is strengthened between Indonesia through such occasions as Bilateral Document on Climate Change Cooperation between Indonesia and Japan on November 2011 and Joint Statement between Ministry of Forestry Indonesia and JICA on Cooperation on Climate Change in Forestry Sector on March 2012.

IJ-REDD+ Project

Ministry of Forestry Indonesia and JICA have agreed to conduct a new project for REDD+, "Indonesia-Japan Project for Development of REDD+ Implementation Mechanism (IJ-REDD+)", that has started June 2013 as a 3 years technical cooperation until 2016. IJ-REDD+ is aiming to support development of REDD+ mechanism and its enabling conditions in Indonesia through integrated approach of national, sub-national and site levels.

Target provinces of IJ-REDD+ will be West Kalimantan and Central Kalimantan. Kalimantan Island is characterized with rich forest resources and fast deforestation rate. Both provinces have significant area of peat land, and, therefore, sustainable management of forests and peat land is a key to reduce GHG emission. In West Kalimantan, four districts, i.e. District Ketapang, District Kayong Utara, District Kubu Raya, and District Pontianak, are targeted districts of IJ-REDD+. In site level, Gunung Palung National Park is the pilot lite for developing the national park REDD+ model (Fig 1).

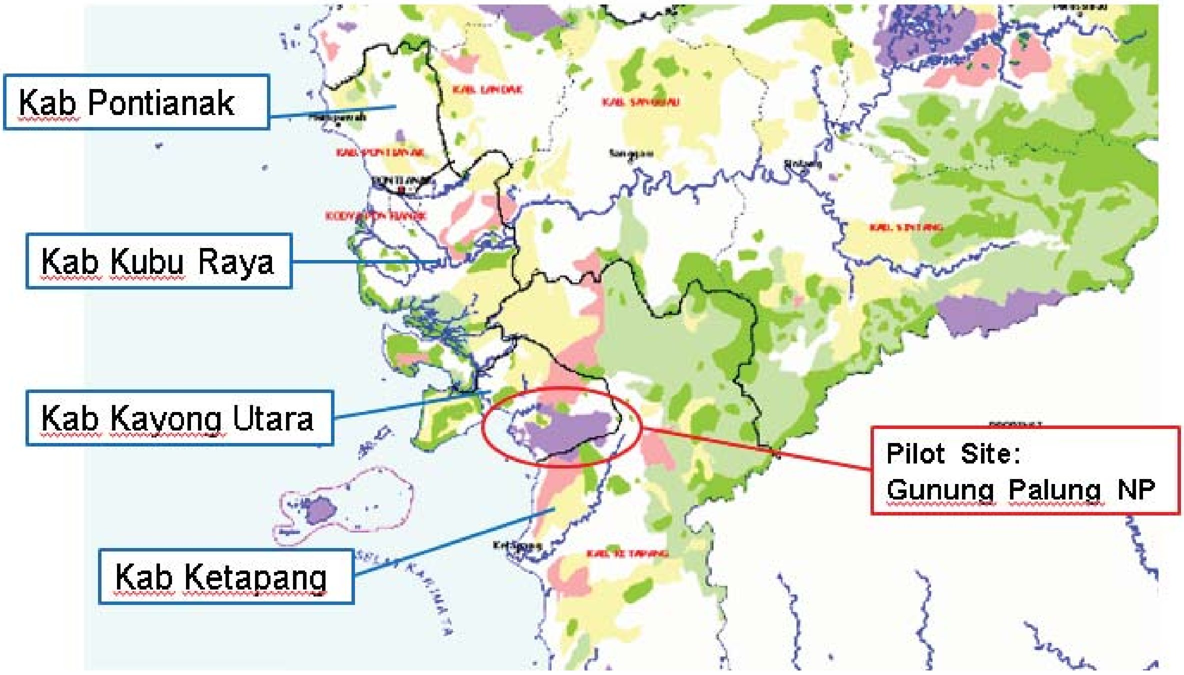

Fig. 1 Target Districts and Site of IJ-REDD+ in West Kalimantan

Project purpose of IJ-REDD+ is to develop REDD+ implementation mechanism in West and Central Kalimantan. There are five outputs of IJ-REDD+, among which, from Output 1 to 3 will be carried out in West Kalimantan. Output 4 will be carried out in Central Kalimantan mainly as provincial level activities, while Output 5 conducted in national level. Outline of activities of each output is as follows (Fig. 2);

Output 1: To support establishing the provincial level REDD+ mechanism including RL/REL analysis as well as other related policy initiatives including implementation and monitoring of RAD-GRK (Regional Action Plan for GHG Emission Reduction).

Output 2: To support developing a REDD+ model in national park (Gunung Palung National Park), including collaborative management with communities in terms of conservation and sustainable management of the national park and surrounding areas, carbon monitoring, social and environmental safeguards, formulation of Project Design Document as a REDD+ project.

Output 3: To support developing REDD+ models in production forests, protection forest and non-forest land.

Output 4: Activities under output 4 are carried out in Central Kalimantan, mostly concentrated to support provincial level MRV institution and capacity building. One important factor for MRV in Central Kalimantan is how to measure emission from peat land, and for this aspect, close collaboration with JICA-JST Project on Wild Fire and Carbon Management in Peat Forest is in scope.

Output 5: Activities under output 5 are conducted in national level and aimed to make the findings of IJ-REDD+ be referred to in the development of national level REDD+ mechanism. IJ-REDD+ also is aiming to support policy development related to climate change and REDD+ in national level.

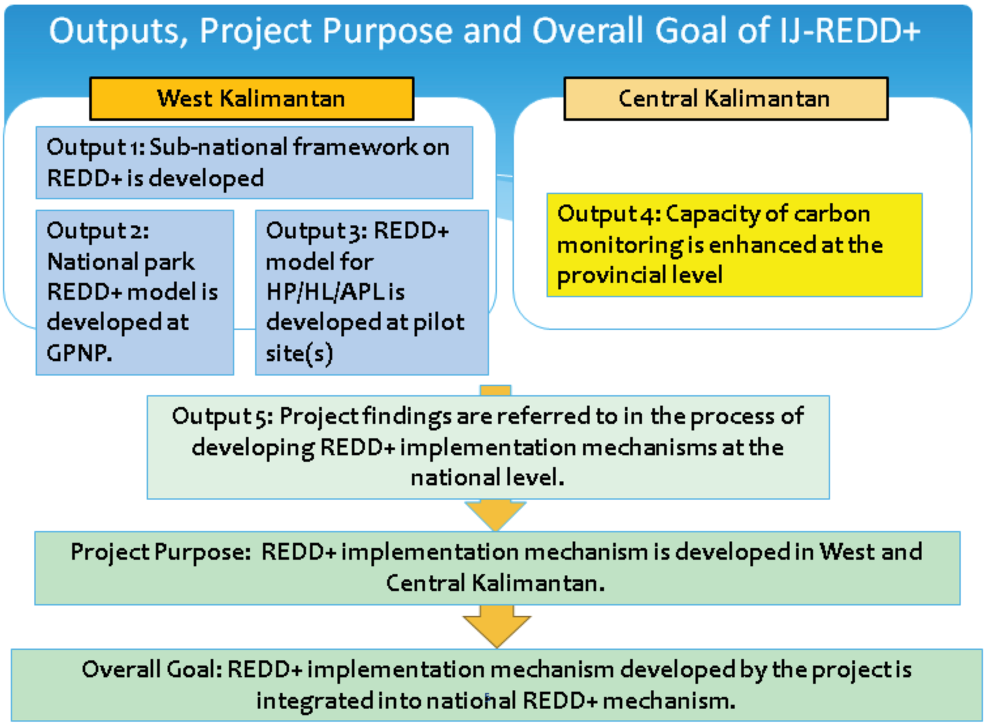

Fig 2. Output, Project Purpose and Overall Goal of IJ-REDD+

Collaboration with JICA-JST Project and IJ-REDD+

Regarding GHG emission in land sector, one of the important factors which are characteristic in Indonesia is existence of a large area of peat land. Emission from peat land accounted for 26% of total emission of Indonesia, not including emission from land use conversion and forestry in 2014. National REDD+ Strategy of Indonesia, prepared by REDD+ Task Force and enected in September 2012, clearly states that peat land is a target of the strategy as well as natural forests.

However, there are gaps in institutional and technical capacity in monitoring emission from peat land which contains vast amout of underground carbon stock. Although methods for monitoring emission from land use changes on mineral soils are already standardized in certain extent by using satillite image analysis of monitoring land use change coupled with measuring carbon stock of different vegetations based on ground sample plots, there still lacks the standarlized MRV method for measuring emission from peat land applied in policy making and monitoring, due to lacking of data availability regarding emission factor and activity data of peat land, gaps in human resource and institutional capacity of peat land management and monitoring.

One of major outcomes of JICA-JST project is to develop an integrated model for measuring emission from peat land, such as Hirano Model of estimating Net Ecosystem CO2 Exchange (NEE) by modeling relationship between ground water level and CO2 emission. Other outcomes ranging from peat fire management, silvicultural techniques and ecological knowledge are considered to have a significant impact towards overall sustainable management of peat land, as well as measuring emissions from peat land.

One of the expected roles of IJ-REDD+ project is, in collaboration with JICA-JST project, support sub-national MRV of REDD+ and RAD-GRK in Central Kalimantan by bridging the advanced research findings of JICA-JST project to stakeholders of policy implementation and monitoring through facilitation and capacity building.

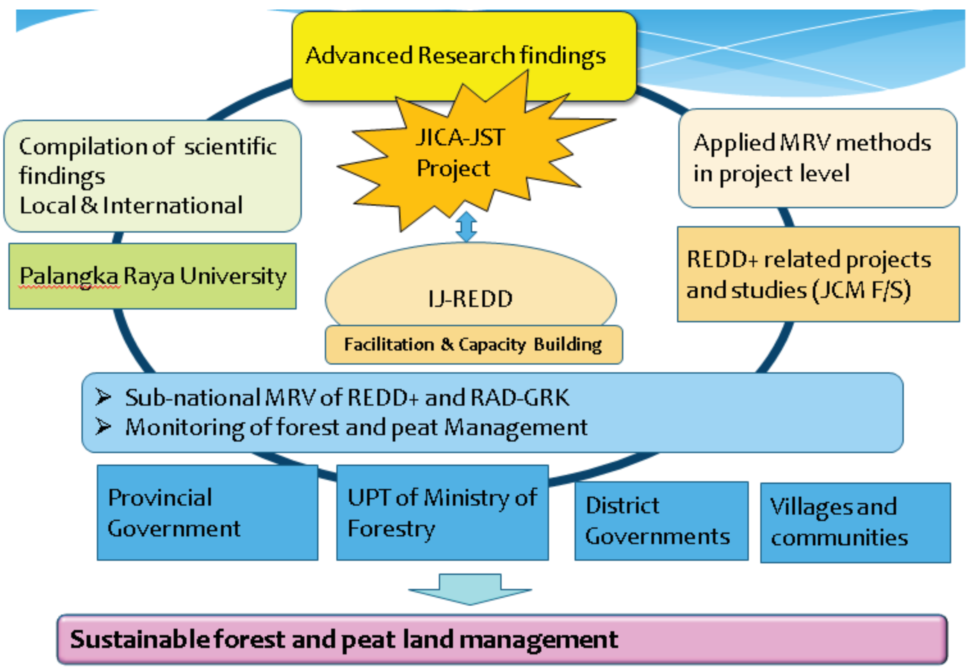

Fig.3 Role of Stake-holders in Central Kalimantan

Conclusions

REDD+ is considered as a prospective mechanism to enhance sustainable management of forests and peat land. MRV (measurement, reporting and verification) is an important element for development of the REDD+ mechanism. However there are still technical and institutional gaps for MRV particularly of peat land emission. IJ-REDD+, in collaboration with JICA-JST project, could contribute to filling in those gaps through bridging advanced scientific findings and relevant stakeholders in policy making, implementation and monitoring.

Acknowledgement

The author would like to express sincere appreciation to Ministry of Forestry Indonesia and JICA for making this presentation possible.

References

JICA and Ministry of Forestry Indonesia (2012). Field Notebook “JICA Cooperation on REDD+ in the Forestry Sector in Indonesia

Government of Japan (2011). Press Release “Issue of the document of Bilateral Cooperation on Climate Change between the Government of Japan and the Government of Indonesia“

Indonesian REDD+ Task Force (2012). REDD+ National Strategy

Peat soil subsidence, water table and CO_2 flux

G. Inoue[1)], M. Kawasaki[2)], A. Sakurai[3)], K. Kusin[4)], S.H. Limin[4)]

[1)] University of Tokyo
[2)] Nagoya University
[3)] Nippon-Koei Co.
[4)] University of Palangka Raya

We have installed compact insturments at a site in Parangka Raya of Central Kalimantan, Indonesia. The change of peat soil thickness is 4.5-6.1 % of the under-ground water level change, mostly due to consolidation by water loss.

Key words: MRV, distance meter, microbial decomposition, peat shrinkage.

Introduction

Drainage of tropical peatlands causes irreversible lowering of the surface as a consequence of peat shrinkage and biological oxidation, with the latter resulting in a loss of carbon stock. Rapidly increasing peat carbon losses from drained tropical peatlands of south-east Asia, mostly in Indonesia and Malaysia,have been found to contribute substantially to global greenhouse gas emissions.[1]

Limin's group of University of Parangka Raya, has estimated net carbon losses from peatlands drained for agriculture and compared it with that from undrainaged one in Central Kalimantan of Indonesia. The loss rate of drainaged Kalampangan forest is 7.4 kg-C/m2/yr while 3.5 kg-C/m2/yr from undrainaged NLPSF-Sabangau forest.[2] Annual peat swamp forest ecosystem level carbon balance is labile (±0.6 kg-C/m2/yr), while drainage and other disturbances (haze, biomass removal etc.) cause net carbon-loss from the ecosystem. [3, 4]

To calculate the net change in peat carbon stock from the difference between all estimated fluxes into and out of the peat, we need a simple and reliable approach to determining net carbon losses from drained tropical peatlands, especially in view of the urgent requirement for land use planning policies that reduce CO2 emissions from peatlands. In general subsidence is 10% of the groundwater level. Thus, drainage to 10 cm causes a subsidence of 1 cm/year. Each cm subsidence emits 13 t-CO2/ha/yr. Here we propose a compact instrument in combination with water-table depth measurement.

Method

We describe here a compact instrument for measuring subsidence utilizing a commercially available laser distance meter (Keyence) attached with a battery-driven data logger (HIOKI) as shown in Fig. 1. It has a precision in distance <50 μm and is installed as shown in Fig. 2. The laser distance meter of Fig.1 is installed on a pole which is inserted reaching to the mineral soil layer below peat soil. The distance change between a target put on soil surface and the distance meter on the pole corresponds to the peat-soil thickness change. A water level sensor (Hobo, series U) is attached to the soil level sensor, which measures simulataneously the under-ground water-level on the site.

Results and Discussion

We have installed five insturments at a site in Parangka Raya (S2.12º E113.54º) of Central Kalimantan, Indonesia. Two typical results will be shown below. Figure 3 shows the peat-soil thickness change above clay layer and corresponding under-ground water level from October of 2012– February of 2013. Based on these data the change of peat soil thickness is about 4.5 % of the under-ground water level change as shown in Fig. 4. From March till June of 2013, the correlation between soil- and water levels was better and the soil-level change is 6.1% of water-level change as shown in Fig. 5.

Subsidence of peat-land is possibly caused by three processes: 1) consolidation by water loss (compression of water-saturated peat below water table), 2) loss of peat-soil through the microbial decomposition converting soil to CO2, and 3) compaction and shrinkage by pressure applied on soil surface (volume reduction above water table). Subsidence is caused mostly by Process 1. Concerinng Process 2, assuming that the flux of CO2 by microbial decomposition is 4 g C/m2/ day and soil density is 0.3, peat-soil thickness is expected to decrease by 4 mm in 120 days, which is much smaller than the compact/swelling process 1. Process 3 can be neglected in the present measurement.

This work is sponsored by JICA-JST and GRENE-ei programs.

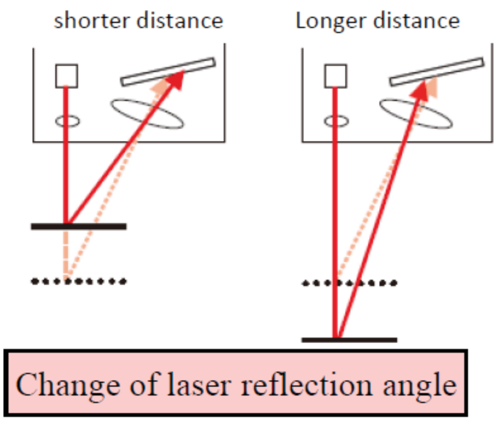

Fig. 1. Schematics of principle of the laser distance meter for measurement of subsidence in a peatland.
A combination of laser and reflected light detection system measures a change in soil level.

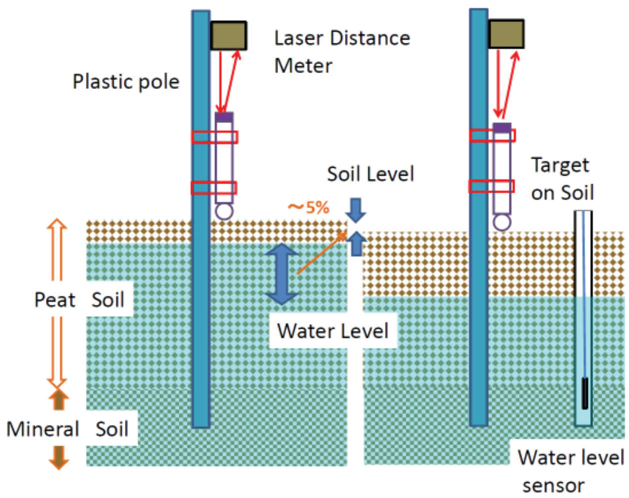

Fig. 2. Layout shows a change in peat-soil thickness above clay layer. (left) before subcidence, (right) after subcidence by loss of under-ground water level.

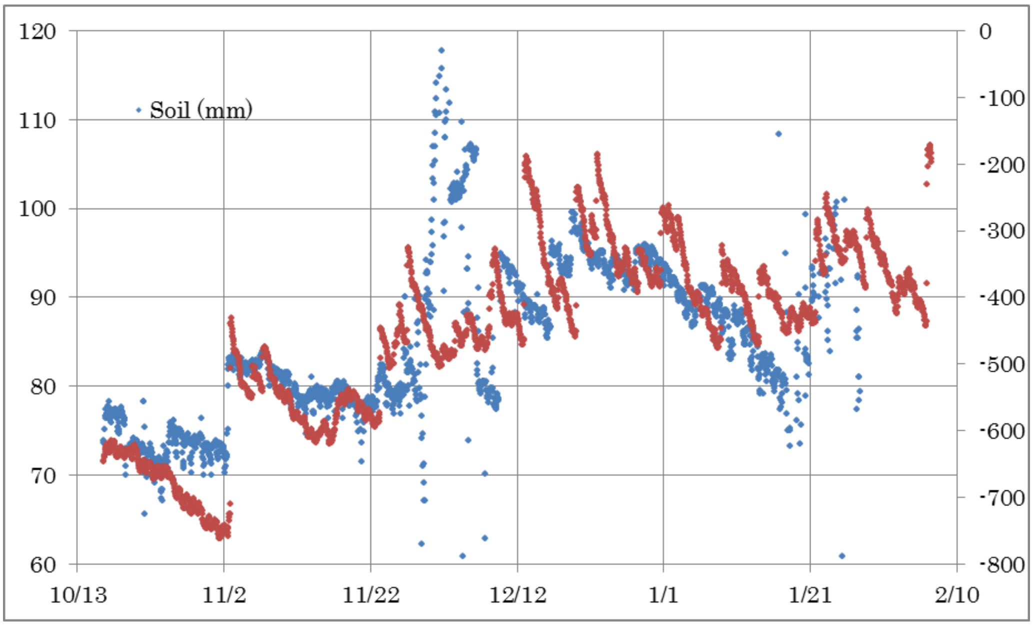

Fig. 3 Change of peat-soil thickness above clay layer (blue, left scale in mm) and under-ground water level (red, right scale in mm). Measurement from October of 2012– February of 2013.

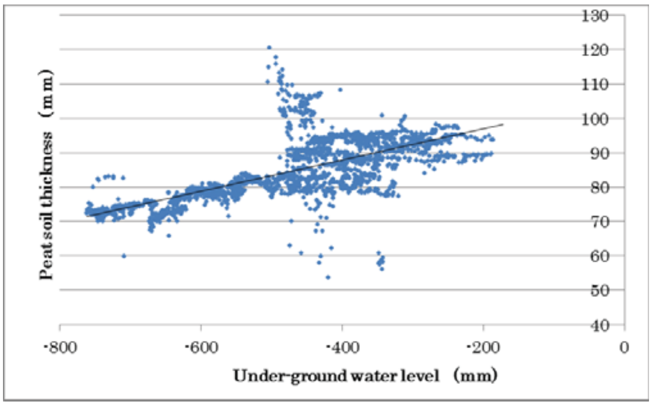

Fig. 4 Peat soil thickness change (mm) vs. under-ground water level change (mm) from October of 2012– February of 2013. The slope of the solid straight line is 0.045 and R2 is 0.45.

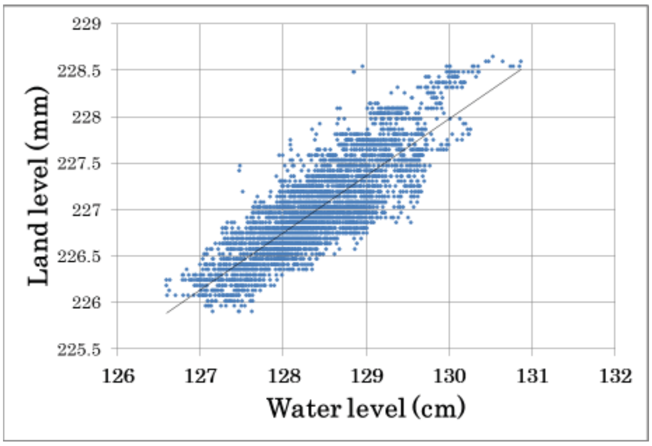

Fig. 5 Peat soil thickness change (mm) vs. under-ground water level change (cm) from March-June of 2013. The slope of the solid straight line is 0.61 and R2 is 0.69.

References

1 S. Hooijer. J. Page, J. Jauhiainen, W. A. Lee, X. X. Lu, A. Idris, G. Anshari, Biogeosciences, 9, 1053–1071 (2012)

2 S. H. Limin, J. O. Rieley, S. E. Page, H. Vasande ,J. Jauhiainen, H. Wosten, MRV meeting, (Sapporo, 5 – 7 July, 2008)

3 T. Hirano et al., Global Change Biology, 13, 412–425. (2007)

4 Suzuki et al. Environment-Control-in-Biology, 37, 115-128. (1999).

Spatial and temporal variation of above ground biomass in tropical dome-shaped peatlands measured by Airborne LiDAR

Veraldo Liesenberg[1)], Hans-Dieter Viktor Boehm[2)]*, Hans Joosten[3)] and Suwido Limin[4)]

[1)] Faculty of Geosciences, Geotechnique and Mining, TU Bergakademie Freiberg, Bernhard-von-Cotta-Str. 2, D-09599, Freiberg (Sachsen), Germany, now with UNI Campinas, Brazil.
[2)] Kalteng Consultants [www.kalteng.org], Kirchstockacher Weg 2, D-085635, Hoehenkirchen (Bayern), Germany.
[3)] Institute of Botany and Landscape Ecology, Universität Greifswald, Grimmerstr. 88, D-17487 Greifswald (Mecklenburg-Vorpommern), Germany.
[4)] Universitas Palangka Raya and CIMTROP, Jalan Yos Sudarso, I-73112, Palangka Raya (Kalimantan Tengah), Indonesia.

* E-mail address: viktorboehm@t-online.de

Southeast Asian tropical peat swamp forests (PSF) are important for their large carbon stock storage and rich biodiversity. Reports suggested that PSF display specific surface patterns linked to hydrology which reflects on biodiversity, vegetation structure and carbon dynamics. On the other hand, excessive peat subsidence has been recorded in both degraded PSF areas and excessive drained peatlands. Therefore, the key importance of PSF to ecological processes, their resilience for forest degradation and logging highlights the need for a comprehensive forest monitoring in which LiDAR technology may play an important task.
Three small-footprint LiDAR transects were acquired in July 2007 and 2011 using the Riegl LMS-Q560 system. Each transect encompasses an ecological peat dome gradient ranging from the river system to the peat dome. The three transects faced in the past different forest degradation intensities. The transects are located at the Sabangau National Forest (one site) and the Mawas Reserve (two sites) in Central Kalimantan, Indonesia. Our main objectives were to map changes in the vertical structure of the PSF (canopy height), to relate different height metrics, and Above Ground Biomass (AGB), and from these maps to identify both sources and sinks of carbon across the three-peat dome-shaped gradients. AGB values were related to in-situ field measurements.

The spatial patterns of biomass changes matched expected patterns given the distribution of PSF physiognomies and previous forest disturbance history. Pairwise comparisons showed that the canopy top height changes are coincident with expected changes based on the different PSF physiognomies. Undisturbed PSF showed similar canopy heights between the period of 2007 and 2011, while degraded PSF had net gain in average of up 2m. As a result, the AGB map (derived at 1ha sample plots) showed most of the PSF as a carbon sink, with widely scattered and isolated areas as neutral (no net biomass change) and sinks caused by both dieback effects and current logging activities.

The quantification of the AGB changes and the sensitivity of LiDAR to characterize the vertical structure of the PSF may help further development under the Reducing Emissions from Deforestation and Degradation (REDD+) mechanism.

Keywords: Peat Swamp Forest, Peat Dome Slope, self-regulation mechanism, LiDAR, airborne laser scanning, change detection, REDD, Kalimantan and EMRP.

Introduction

Peatlands originally cover more than 25 million hectares of the coastal areas of the Southeast Asia archipelago (Page et al., 2004, Page and Banks, 2007). These peatlands are basically terraces or dome-shaped dominated by trees with a surface isolated from mineral soil-influenced groundwater receiving water through precipitation only (i.e. ombrogenous peat swamp forest, henceforth PSF). PSF are of global importance for their rich biodiversity and the huge amounts of carbon stored (Sieffermann et al., 1992, Sorensen 1993, Page et al. 2002, Hirano et al. 2007).

In recent years the PSF have increasingly been drained, logged, and converted to farm land and oil palm and acacia plantations (Boehm and Siegert, 2004, Miettinen and Liew, 2010). The awareness of the consequent greenhouse gas emissions, from biomass reduction by deforestation and forest logging and not last peat subsidence by oxidation and compaction has created strong political support for reducing these emissions in the framework of the reducing emissions from deforestation and degradation (REDD) protocols (Gibbs et al., 2007). Efforts have been made in this regard by decreasing the rate of deforestation and forest degradation and by rewetting and reforesting selected areas of Indonesia (Jaenicke et al., 2008, Page et al., 2009).

In undisturbed peat swamp domes, the vegetation and associated surface relief used to function as hydrological 'self-regulation' mechanisms that secured permanent water saturation and might made the domes exceptionally resilient against climate change (Dommain et al. 2010, 2011). Typical for this self-regulation phenomenon is the concentric arrangement of PSF physiognomies and micro-relief patterns conditioned by the arrangement of hummocks and aerial roots (Anderson 1983, Joosten 1993, Dommain et al., 2010, Boehm et al., 2010). Modelling results (Couwenberg and Joosten 2005) show how in the centre of a dome, weather conditions favour the establishment of more permeable elements that readily permit water flow to the edges (Bakker, 1992). Whereas towards the margins, drier conditions favour less permeable elements that limits lateral runoff (Takahashi and Yonetani, 1997). The vegetation itself and relief patterns that generate these hydrological feedback mechanisms on a landscape level are on the local level also conditioned by surface topographic variables such as dome slope due to slight changes in altitude from the river system to the peat dome plateau (Page et al., 1999, Couwenberg and Joosten 1999, 2005, Boehm et al., 2010, 2013). The dome slope may also drive changes in the vertical structure and spatial arrangement of the vegetation in a peat dome due to a coupled stressing effect by water saturation and exposure to weather conditions. However, the relationship between the vegetation height and topographical variables such as the dome slope has not yet been confirmed by remotely sensed observations in such tropical PSF environments.

Remotely sensed measurements proved already to be a useful tool in such endangered environments for several applications, and not last, serving as a tool for the policy and management of natural resources (Boehm and Siegert, 2004, Korpela et al., 2009, Miettinen and Liew, 2010). However, a good single sensor to retrieve both vertical structure of the forest and ground surface is the Light Detection and Ranging (LiDAR) system whose performance overcomes both optical and microwave sensor retrievals, respectively (Hajnsek et al. 2009, Boehm et al., 2010, 2013, Asner et al., 2012).

Although limited on the spatial coverage and temporal acquisition interval due to its relative acquisition cost, compared to other remotely sensed systems, airborne LiDAR measurements based on transects with a considerable swath, and acquired from the river system to the peat dome plateau are still representative for ecological studies.

Materials and Methods

Study area description

The study area encompasses four LiDAR transects in three test sites located in Central Kalimantan, Indonesia (Fig. 1). They represent different peat dome relief shape and intensities of past forest log. Mawas encompass two test sites and is located at the northeast part of block E of the Ex-Mega Rice Project (EMRP) (Figs. 1a, 1b) between river Kapuas and towards river Barito, whereas the Sabangau test site is located inside the Natural Peat Swamp Forest Laboratory (NPSFL) and managed by the Centre for International co-operation in sustainable Management of TROpical Peatland (CIMTROP) and is located inside the Sabangau National Park (SNP) (Fig. 1c). Sabangau and Mawas km238 (south of equator) transects were partially damaged by peat fires during the El Niño Southern Oscillation weather effect in 1997 (Page et al., 2002, Usup et al., 2004).

The three selected test sites are relatively flat. According to Shepherd et al. (1997) and Page et al. (1999) the peat thickness of Sabangau test site varies from 0 to 12m. Estimates conducted by Jaenicke et al. (2008) using GIS techniques showed that the peat thickness varies from 0 to 18m at Mawas sites. The climate of the entire study area following the Köppen climate nomenclature is humid tropical rain forest (Af).

The monsoon occurs between November and April and the average annual rainfall and air temperature are 2500mm and 25oC respectively (Usup et al., 2004). The selected LiDAR transects consist of altered primary forest patches, in which trees have been already selectively logged until the end of the 1990s. However, drainage channels at Mawas and Sabangau were not close completely and are still being used for illegal logging activities up to date. A detailed description of the vegetation species at Sabangau test site can be found in Shepherd et al. (1997). Hence, at this specific test site, vegetation species richness has been related to soil properties and peat thickness (Page et al., 1999) and gibbon density (Hamard et al., 2009).

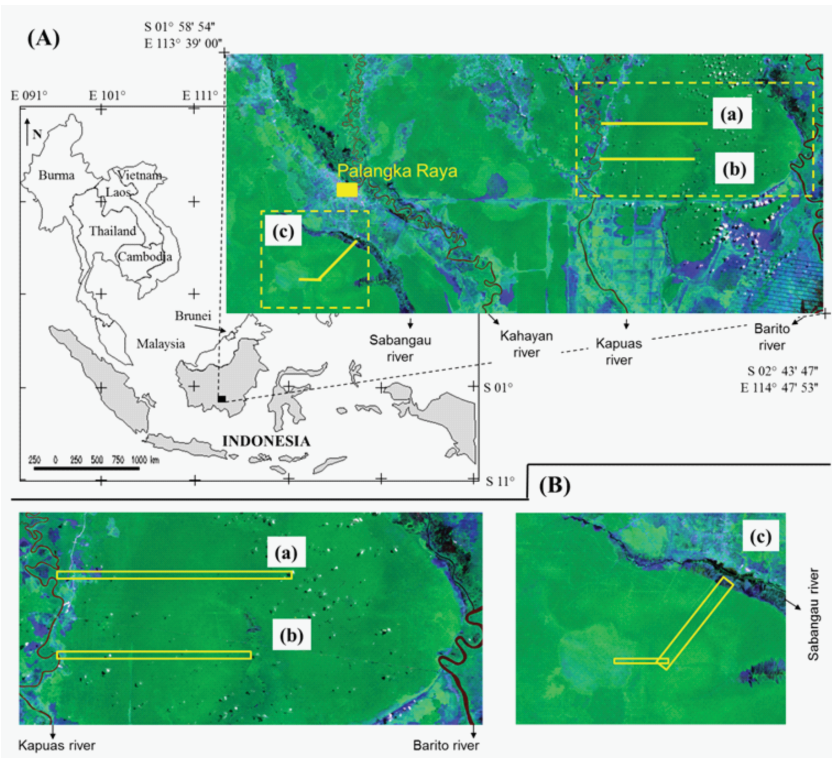

Figure 1. Location of the study area in Central Kalimantan, Indonesia (top) and location of the three selected test sites (bellow). The yellow rectangle shows the location of the Palangaka Raya

city. The solid yellow lines indicate the LiDAR transects (A). Lower part of the image indicates in order: Mawas km228 south of equator (a), Mawas km238 (b) and Sabangau (c). Each test site is indicated in more detail over the Landsat-7/ETM+ acquired on August 5, 2007 (3R4G5B).

LiDAR acquisition and preprocessing

The LiDAR transects were surveyed twice by Kalteng Consultants and Milan Geoservice GmbH from August 5 to 7, 2007, and August 4 to 5, 2011, using a Laser Scanner System Riegl LMS-Q560. It was attached to a Bell 206 helicopter for the first flight and a BK117 helicopter on the second flight. The nominal height was in average 530m for both surveys. A differential global positioning system (DGPS) reference station was mounted at the airport of Palangka Raya city considering an elevation of 25.0m or 82 feet. The position and orientation of the LiDAR system on the helicopter was measured by an Inertial Navigation System (INS) and a differential GPS located on the tail boom respectively on the cockpit roof with 256Hz. A complete description of the LiDAR survey can be found in Boehm et al. (2007, 2008). Technical details of the LiDAR systems are further detailed in Table 1.

Scan Angle (field of view)	±30 degrees
Swath width (m)	□ 500m
Scan Frequency (kHz)	66 to 100
Vertical laser beam accuracy (m)	≤ 0.15m
Horizontal laser beam accuracy (m)	≤ 0.5m (both x- and y- directions)
Laser beam (mrad)	0.5 (footprint up to 30cm)
Laser Wavelength (µm)	1.55 (near-infrared)
Point density (points/m2)	1.4* and 3.5**
Ground resolution (pixel size)	0.5m for both DTM and DSM

Note: for the flight measurements taken in *2007 and ** 2011.

Table 1. Specifications of the airborne LMS-Q560 LiDAR (Riegl) system and its data products

Ground backscattering passing through dense PSF amounted from 1% to 3% of the total laser beams. The processed laser beams were classified into ground surface and over ground classes using a terrain-adaptive bare earth algorithm for both dates. The algorithm is integrated with the Cloud Peak software (LASEdit) and in an IDL software used by company Milan and provides an unsupervised classification of the cloud points and adapts it to a hypothetical bare earth condition. The triangular irregular network (TIN) was used to construct based on a delaunay triangulation. Then a square grid of pixels was extracted for each TIN using linear interpolation for both ground and over ground layers in both acquisition dates. The classified laser representing the ground surface were converted in a digital terrain model (DTM), and the canopy surface into a digital surface model (DSM), respectively, both with a spatial resolution of 1m. The difference between DSM and DTM provided us the canopy height model (CHM).

Radiometric, geometric and off-scan line corrector (SLC) corrections were performed on a Landsat-7/ETM+ scene acquired on August 20, 2001, August 5, 2007 and June 13, 2011 (path/rows 118/61-62). It also coincides with the both LiDAR surveys. The Landsat data was then converted to the hemispherical directional reflectance factor (HDRF) using the Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) algorithm, which is based on a MODTRAN4 approach for path scattered radiance, absorption, and adjacency effects. Spectral signatures extracted from the Landsat data were used for spectral characterization and support for the LiDAR analyses. Due to the strong haze and cloud coverage, the results were basically restricted to Sabangau test site.

LiDAR Data Analysis

1-ha sample plots (100x100m) were selected from each LiDAR transect with a regular spacing between plots of 200m for both Mawas transects (Figs. 1a,b). All Laser beams in this 1-ha sample plots were analyzed for the DSM and DTM data using the Global Mapper software. At the Sabangau transect the distance was variable taking into account the establishment of in-situ field measurements (Fig. 1c). The variation in the distance of two sample plots was necessary to avoid as much as possible the influence of the drainage channels, degraded forest patches and former railways used in the past for timber transportation. In each sample plot we accounted for different LiDAR derived CHM parameters such as the average of the trees, the maximum tree height and the dominant tree height. The last parameter was obtained using a local maximum filter algorithm and is reported to be a good indicator of the emergent forest strata in the tropics. Field measurements were performed during July and August, 2011. A total of 52 sample plots we measured with a sample plot of 10x50m (Boehm et al., 2013).

Biophysical properties of the vegetation such as the diameter at breast height (DBH) higher than 5cm were measured, and were used for the tree basal area (TBA) determination. Above ground biomass (AGB) was estimated for the Sabangau test site using the allometric equation proposed by Brown (1997) for moist forest (Eq. 1).

$$\text{AGB}= exp^{[-2.13+2.53\times \ln (DBH)]} \qquad Eq.1$$

Other AGB allometric formula for the tropics can be found in Chave et al., 2005 and Kronseder et al., 2012. Thus, total tree height and up to the first branch, crown diameter and form, trunk quality and geographical position were measured. The field measured parameters in the field were extrapolated per ha and related to the LiDAR sample plots of 1ha. Additionally, the estimation of canopy coverage (CC) and plant area index (PAI) through hemispherical photographs was performed. PAI differs from leaf area index (LAI) since it has not been corrected for the woody-to-total area ratio.

Peat surface slope was obtained by calculating the difference of DTM values between two sample plots and their respective distance. In the slope determination, the averaged DTM value was used in order to minimize the inclusion of signals from the understory vegetation, tree trunks and branches lying on the ground. These analyses were conducted for both surveys (e.g. 2007 and 2011). The tree height variations were computed for each test site and related to dome slope through the use of linear regression. Roughness was obtained taking into account the difference between the highest and the slowest ground points and were representative of the hummocks and hollows variation.

The resilience of the PSF was analyzed through the peat subsidence and forest regrowth. Forest regrowth was obtained following with the subtraction of the bi-temporal CHM (i.e. CHM2011 minus CHM2007). The peat surface subsidence was determinate with the subtraction of the bi-temporal DTM (i.e. DTM2011 minus DTM2007). The results were also employed for the peat dome characterization and related to previous forest log/degradation and Landsat signatures. Ortho-Photos taken by a Hasselblad camera acquired during the second LiDAR survey and in-situ photos were used to show demonstrate the current scenario of the peat domes. Results of forest regrowth and subsidence were afterwards related to peat roughness, dome slope and also each other, and finally discussed for each test site.

A flowchart of the methodology involving LiDAR data processing is shown in Figure 2. Estimation of the amount of carbon release to the atmosphere was not taken into account due to the unavailability of local bulk density measurements as well as uncertainties of factors such as the percentual of oxidation, compaction and lixiviation. Such analyses required specific modelling and are beyond the scope of this investigation.

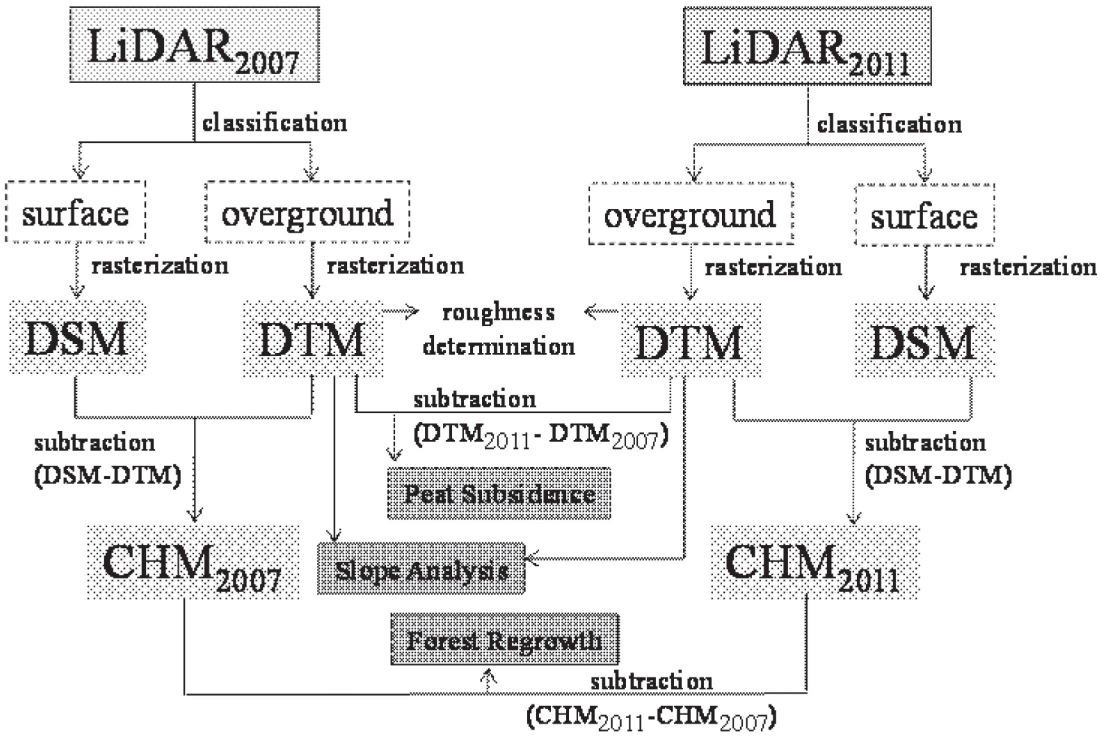

Figure 2. Schematic diagram of the LiDAR data processing flow applied to this study.

Results and Discussion

LiDAR derived parameters

The peat surface of the selected transects, represented by the LiDAR derived DTM, show from the river system to the near-horizontal dome plateau an increasing surface gradient of up to 15m (Table 2a, Fig. 3). The selected transects are characterized by a considerable topographic heterogeneity with a roughness ranging in average from 0.68m at Mawas km228 to 0.94m at Sabangau transect (Table 2a). Roughness is a good indicative of the ground heterogeneity between hummocks and hollows. Trees are usually growing on hummocks of root material and litter in this particular ecosystem (Yonebayashi et al., 1997, Brady et al., 2007, Page et al., 1999). Although the DTM was restricted to a low number of laser beams passing through dense canopy in both surveys (i.e. up to 3% of the total beams), the temporal roughness variability between surveys was up to 10% (Table 2a). A summary of the geomorphological characteristics extracted from the LiDAR derived parameters for the selected test sites is shown in Table 2a.

Test Site's Name	Mawas		Mawas		Sabangau	
UTM Latitude	km 228		km 238		km 256 / km266	
LiDAR derived DTM parameters						
	2007	2011	2007	2011	2007	2011
River level (m)	17.8	17.8	17.1	17.1	15.5	15.5
Altitude of the peat dome (m)	**32**	**32**	**29**	**29**	**26/31**	**26/31**
Max. slope (m/km)	2.41	2.90	1.41	1.57	1.71	1.76
Average slope (m/km)	0.62±0.57	0.63±0.60	0.61±0.37	0.55±0.41	0.73±0.43	0.72±0.42
Hummocks roughness (m)	0.73±0.33	1.16±0.22	1.42±0.53	1.12±0.38	0.94±0.15	0.93±0.20
Nominal transect length (km)	23		23		12/17*	
LiDAR derived CHM parameters						
	2007	2011	2007	2011	2007	2011
Dominant tree height (m)	21.8±2.3	24.6±1.6	18.8±2.5	19.1±2.4	21.3±2.2	24.7±1.8
Averaged tree height (m)	13.5±1.8	16.1±1.5	10.9±1.6	13.1±1.6	13.5±2.1	16.3±1.6
Maximum tree height (m)	28.3±3.5	32.1±3.4	25.6±3.9	27.4±3.9	28.5±2.9	29.7±2.4
Number of sample plots	75		91		52	
Past activity log**	slight		heavy/moderated		moderated	

Note: * Sabangau test site is a mosaic of two transects (see Fig. 1c). ** based on the visual interpretation and spectral signatures analysis of Landsat images.

Table 2. Averaged LiDAR derived DTM and CHM parameters for the selected transects in Central Kalimantan, Indonesia.

At the Sabangau transect for example, buttressed and stilt tree roots grow out from the base of the trunk sometimes as high as 2m above the hummocks. The harsh nature of the peat soil reported by Page et al. (1999) at this site from the river system to the peat dome plateau may increase the area of these superficial roots in which inorganic nutrients can be better uptake absorbed from the soil. Thus, trees that grow in such swamp condition have developed also adaptations that allow them to enhance gas exchange from pneumatophores roots during long wet periods (Richter 1984, Bruenig 1990).

Additionally, spreading plank buttresses and dense stilt roots also help keeping indirectly the superficial water saturation by limiting the water percolation across the peat floor through physical barriers such as litter, vegetation and depressions (Herwitz 1988). The water level remains therefore at the uppermost layer of the peat floor for the most of the year implying on a continuous saturation of the water table (Anderson, 1964, Hooijer 2005). This might bring an arrangement of plant communities in mounds (not inundated) and non-mounds (under frequent water saturation) according to their flood tolerance including innumerous pneumatophores and knee roots in non-mounds at specific slope conditions. Hence, large hummocks benefit from the establishment of buttresses and stilt root trees. They have usually many mounds around the base of each tree trunk due to the root architecture supporting aboveground organs raising the peat surface around the buttresses and stilt roots trees (Shimamura and Mimose, 2005, 2007).

Mounds are especially prevalent around huge buttresses and stilt root trees, which form an emergent stratum of the forest (Shimamura and Mimose, 2005). The emergent stratum of the PSF, represented by the CHM dominant tree height, tends to increase from the river system to the steepest part of dome and then to decrease towards to the peat dome plateau (Figs. 3a, 3b). An exception was observed at Sabangau towards to the dome plateau due to the burned scar which leads to lower trees according to the burning severity (Fig. 3c). Tree height increases in average for the selected transects up to 5m if the peat dome slope increases more than 1.3m/km indicating a clear dependence on the dome slope (Figs. 3, 4).

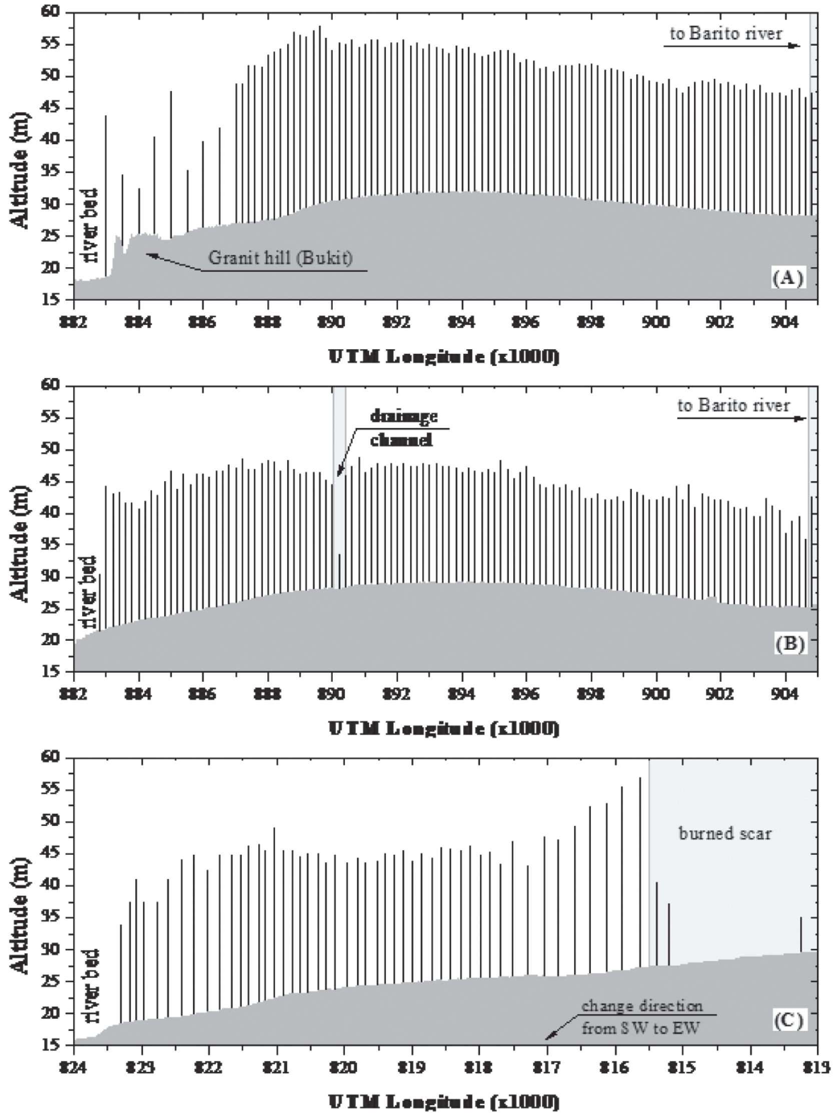

Figure 3. LiDAR derived digital terrain model (DTM) profiles and LiDAR derived canopy height model (CHM) parameter dominant tree height overlaid over the DTM for Mawas km228 south of equator (A), Mawas km238 (B) and Sabangau km256 (C). Results are based on LiDAR measurements acquired in 2007. Each vertical bar is a 1-ha sample plot. Transects have different lengths and vertical scales. Refer to Figure 1 and Table 2 for the selected test sites description.

The averaged tree height varied widely over the selected transects (Figs. 3, 4). This might be due to different intensities of past log intervention to the forest that may explain part of the heterogeneity in the roughness (Table 2a, Fig. 3) and the variations of tree height among the selected transects (Fig. 4, Table 2b). While Mawas km228 has faced less intervention by forest logging, Sabangau and Mawas km238 had experience strong intervention by selective logging through different concession companies until 1997 (Boehm and Siegert, 2004). In such forest logging practices, the large trees are harvested what directly implies on large gaps in the canopy besides the damage of neighbours' trees that further causes a drastic loss in the amount of organic matter inputs. Thus, harvesting practices also includes the construction of small railways and channels to bring the logs out from the forest. These leads to significant changes of the peat floor heterogeneity and their eco-hydrological function. The forest disturbances are still visible on the LiDAR derived products (i.e. CHM and DTM) as well as based on the visual interpretation (Fig. 1) and the spectral analysis of the Landsat scenes (results not shown).

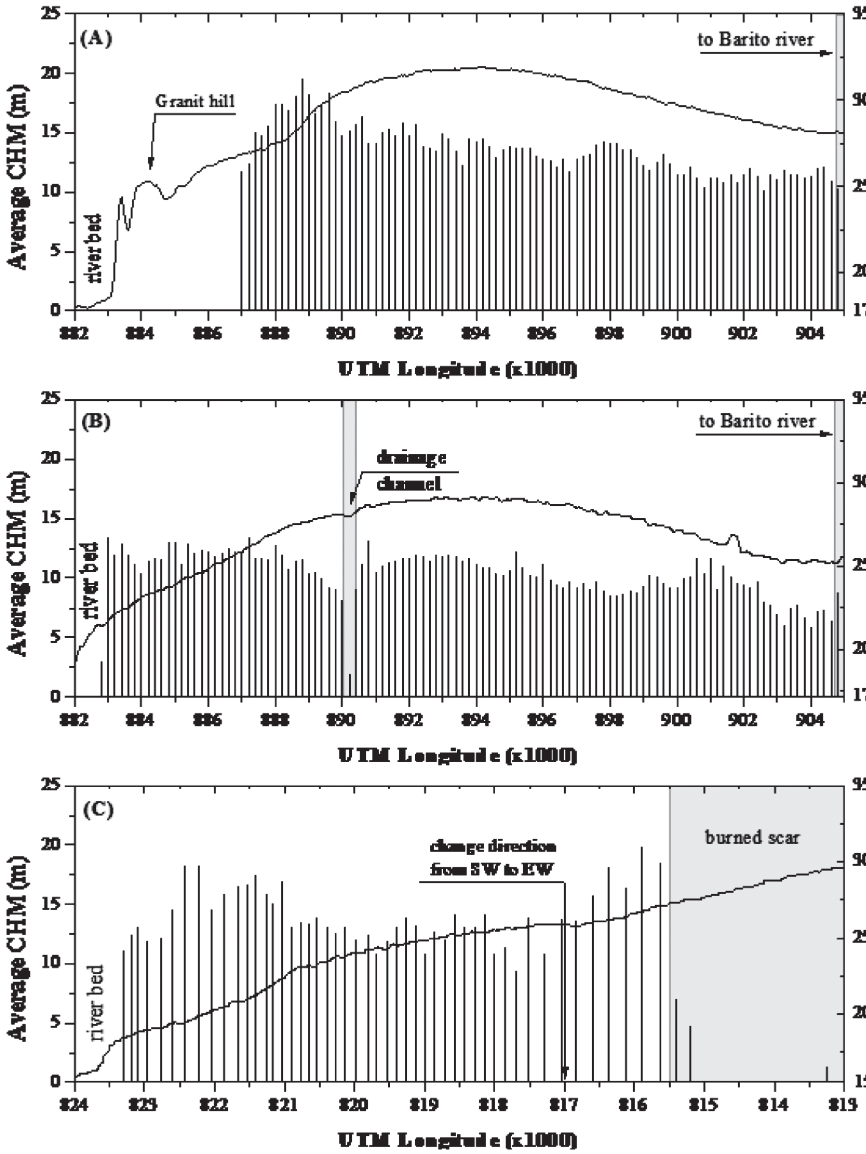

Figure 4. LiDAR derived digital terrain model (DTM) profile and separately LiDAR derived canopy height model (CHM; average tree height) for Mawas km228 (A), Mawas km238 (B) and Sabangau (C). Refer to Figure 1 and Table 2 for the test site description. Results are based on LiDAR measurements acquired in August 5-7, 2007. Each vertical bar is a 1-ha sample plot.

Relationship between tree height and peat dome slope

Linear regression (Fig. 5a) shows that a large part of the forest height at Mawas km228 can be explained by dome slope (up to 80%). Whereas at Mawas km238 and Sabangau this relationship is lower (up to 40%, Figs. 5b, 5c). Thus, the dome slope (Boehm et al., 2010, 2013) tends to explain better the dominant tree height than maximum and averaged tree height (Table 3, Fig. 5).

The extraction of certain commercial species through selective logging and the clear cut of small patches in the forest for hunting practices (Harrison et al., 2011) brought gaps on the canopy layer mainly at the Mawas km238 and Sabangau transects. As a result, faster peat decomposition is noticed due to a reduction on the organic matter supply and an increase on the peat floor surface temperature (Jauhiainen et al., 2005, Ali et al., 2006, Ludang et al., 2007). A homogeneity of the forest canopy is then observed due to the reduction of dominant trees (Figs. 4, 5), consequently also diversity, followed by the establishment of certain pioneer species as a response to increasing offer of light and less competition effects. This may explain the similarity of the different forest attributes in the statistical analysis for the logged transects such as in Mawas km238 and Sabangau transects (Table 3). Thus, these transect show a higher reflectance in NIR and lower reflectance in red than Mawas km228 (results not shown). This indicates higher biomass production, and therefore, more evidences of the secondary stage status of the PSF at Mawas km238 and Sabangau transects (Liesenberg et al., 2010).

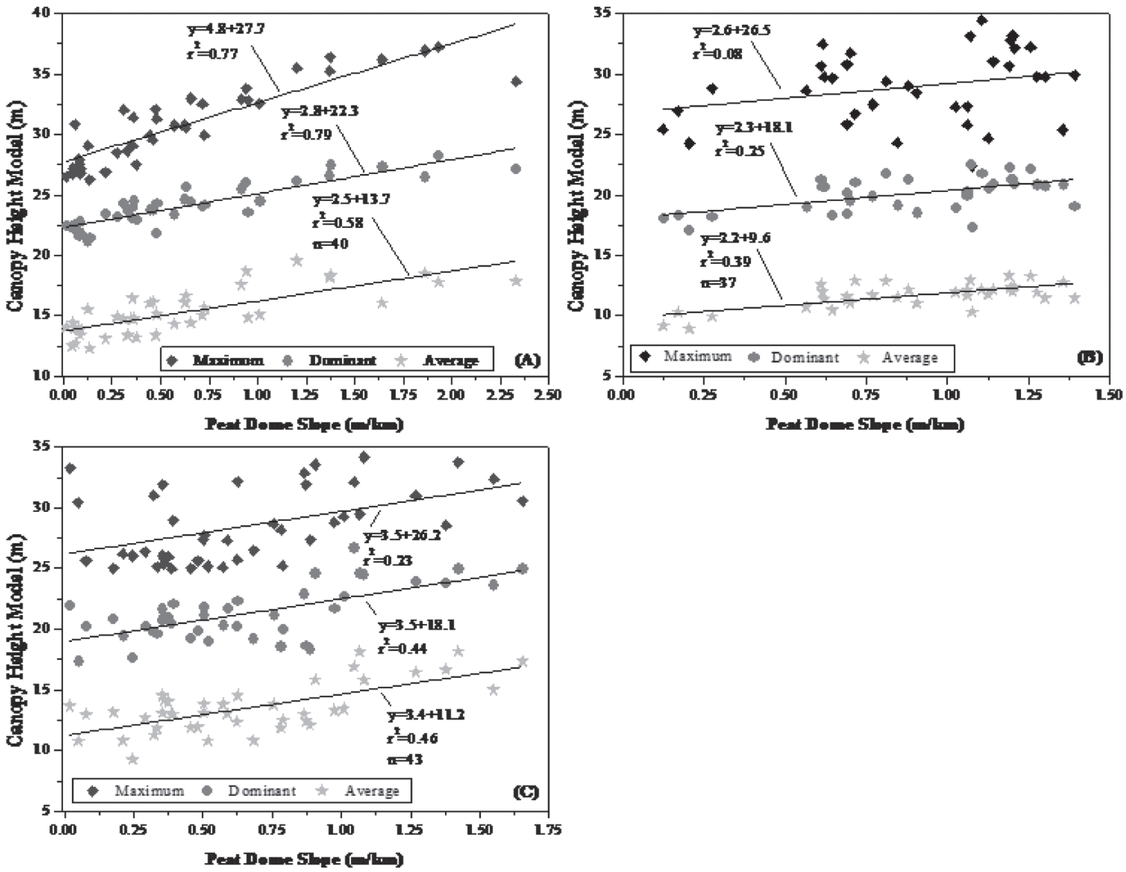

Figure 5. Linear regression models considering peat dome slope versus CHM parameters (i.e. averaged tree height, dominant tree height and maximum tree height) for Mawas km228 south of equator (A), Mawas km238 (B) and Sabangau (C). Refer to Figure 1 and Table 2 for the selected test sites description. Each point represents a 1-ha sample plot. Results are based on the LiDAR acquisition from August 5 to 7, 2007.

	Mawas km 228		**Mawas km 238**		**Sabangau**	
	2007	2011	2007	2011	2007	2011
CHM (maximum)	0.77*	0.80*	0.08	0.08	0.31*	0.30*
CHM (dominant)	0.79*	0.81*	0.25*	0.25*	0.40*	0.39*
CHM (average)	0.58*	0.52*	0.39*	0.39*	0.29*	0.30*
Accumulated subsidence	0.07	0.06	0.08	0.14	0.15	0.20*
Accumulated forest regrowth	0.08	0.07	0.01	0.13	0.06	0.28*

Note: * p<0.000

Table 3. Coefficient of determination (r2) obtained from the linear regression results of peat dome slope versus maximum, dominant and average CHM. Peat dome slope versus accumulated subsidence and forest regrowth.

Changes in tree height may also coincide, at least partially, with surface roughness that acts as small water and nutrient reservoirs. In certain conditions, the supply of mineral nutrients as well as the strategy of cycling and uptaking nutrients efficiently by symbiotic associations and aerial roots (e.g. balance between peat accumulation and peat degradation) is observed in such environments (Tawaraya et al., 2003, Nishimua et al., 2007). However, there was no statistical evidence of the roughness variations according to slope changes (Table 3) most probably due to the multiple interventions into the forest that and the relative low point density at the peat surface. The driest part of the peat dome should occur on the near-horizontal plateau where the soil supply of nutrients becomes progressively more limited since they are more susceptible to runoff to the edges (Anderson 1983, Bruenig 1990, Yamada 1997, Page et al. 1999). The PSF at the steepest dome slope (Boehm et al., 2010, 2013) where the highest trees were observed (Table 3, Figs. 4, 5) is characterized by three to four well-structured canopy layers. Trees have in general stilt and buttresses roots (up to 1/3 of the trees with DBH>15cm) and the peat surface besides large hummocks is also dominated by pneumatophores and knee roots. The understory layer is rich with seedlings and the peat thickness is also higher (Page et al., 1999). Sedges and ferns are more common in large gaps and also in the understory layer towards to the peat dome plateau where the tree height and CC becomes smaller.

Water table fluctuations are larger in high dome slope conditions (i.e. >1m/km) besides nutrient availability driving trees to grow to substantial height (Anderson 1983, Esterle and Ferm 1994, Page et al., 1999). This substantial height also subjects the trees to wind stress (Figs. 4, 5) which further stimulates the expansion of stilt and buttresses roots (Anderson 1983, Richter 1984, Yamada 1997). In addition, the large crowns observed at this part of the dome favor a stronger stem flow that due to the stilt and buttress roots prevents erosion and promote rewetting of their own root system (Herwitz 1988). Hence, it also may favor competitive advantage for other neighbor species (Crook et al. 1997, Shimamura et al. 2006).

The tree height variability was also verified at the Sabangau transect with field measurements (Fig. 6) that similar trends observed by the CHMs (Figs. 4, 5). The agreement with the CHM dominant tree height for the main transect was moderated ($r2=0.51$, $p<0.000$) due to differences between the plots sizes measured in the field twenty times smaller than those from LiDAR used in this investigation. At this site, large TBA (i.e. from 44 to 70 m2·ha-1) and AGB (i.e. from 197 to 360 Mg·ha-1; Fig. 6) variations were also found at the steepest part of the dome. The results also corroborate with the high PAI and canopy coverage values at this peat dome interval (results not shown).

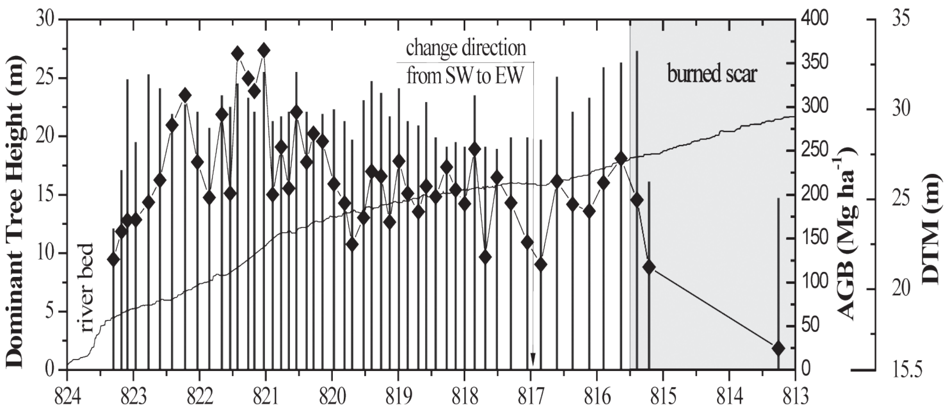

Figure 6. Above ground biomass (AGB) based on Brown (1997). Field measured dominant tree height at the Sabangau test site. High AGB values are found at the highest slope between km 821.5 and km 821. Arrow indicate the change direction of the transect. Refer to Figure 1 for the selected test site description.

Change detection analysis using bi-temporal LiDAR analysis

The aerobic decomposition process of the peat floor in undisturbed PSF is generally faster than the anaerobic decomposition of the bellower peat soil layers (Brady 1997, Chimner and Ewel 2005, Couwenberg et al. 2010). However, long periods of extreme low precipitation can lead to a temporary drought of the peat floor (Wösten et al., 2008). Coupled with forest logging practices and drainage, a subsidence of the peat is therefore favored.

An accumulated subsidence varying from 0.15 to 0.50m (Table 4, Fig. 7) was noticed in the selected transects for the four years period (i.e. from 2007 to 2011). The highest average subsidence was found at Mawas km238 (Table 4, Fig. 7b). Whereas at Mawas km228 and Sabangau the lowest average subsidence values (Table 4, Figs. 7a, 7c). Hence, highest values were commonly found close to drainage channels (Figs. 7a, 7b). At Mawas km238 and Sabangau several small channels are still present and were not completely closed. The channels were dug, usually 1-2m wide and 1m deep with variable length for the transportation by floating to the main rivers and then to sawmills. The subsidence pattern corroborates with previous findings conducted converted PSF into oil palm and Acacia spp. plantations (Hooijer et al., 2012). Hooijer et al. (2013) findings of subsidence in Block A of EMRP are much lower than our findings, private communication 2013.

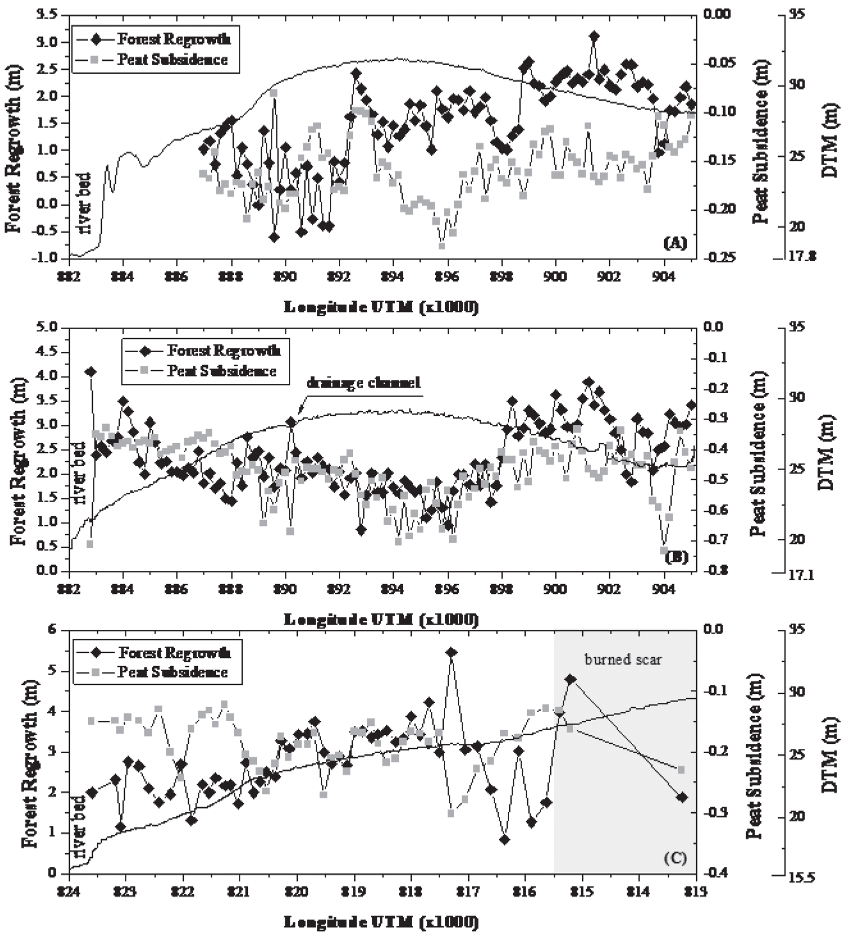

Figure 7. Average forest regrowth and peat surface subsidence for Mawas km228 (A), Mawas km238 (B) and Sabangau (C). Results are based on LiDAR measurements acquired in 2011 and 2007. Transects have different lengths and vertical scales. The arrow indicates the changed direction of the Sabangau transect from the SW to the EW direction. Refer to Figure 1 and Table 4 for the selected test sites description.

Test site's name	**Mawas**	**Mawas**	**Sabangau**
UTM latitude	km 228	km 238	km 256
Average forest regrowth (m)	1.5±1.5	2.1±0.6	3.1±0.75
Peat subsidence (m)	0.16±0.03	0.50±0.1	0.18±0.04

Table 4. Averaged LiDAR change detection results in the time frame from August 2007 to August 2011 (4 years) for the selected three transects in Central Kalimantan.

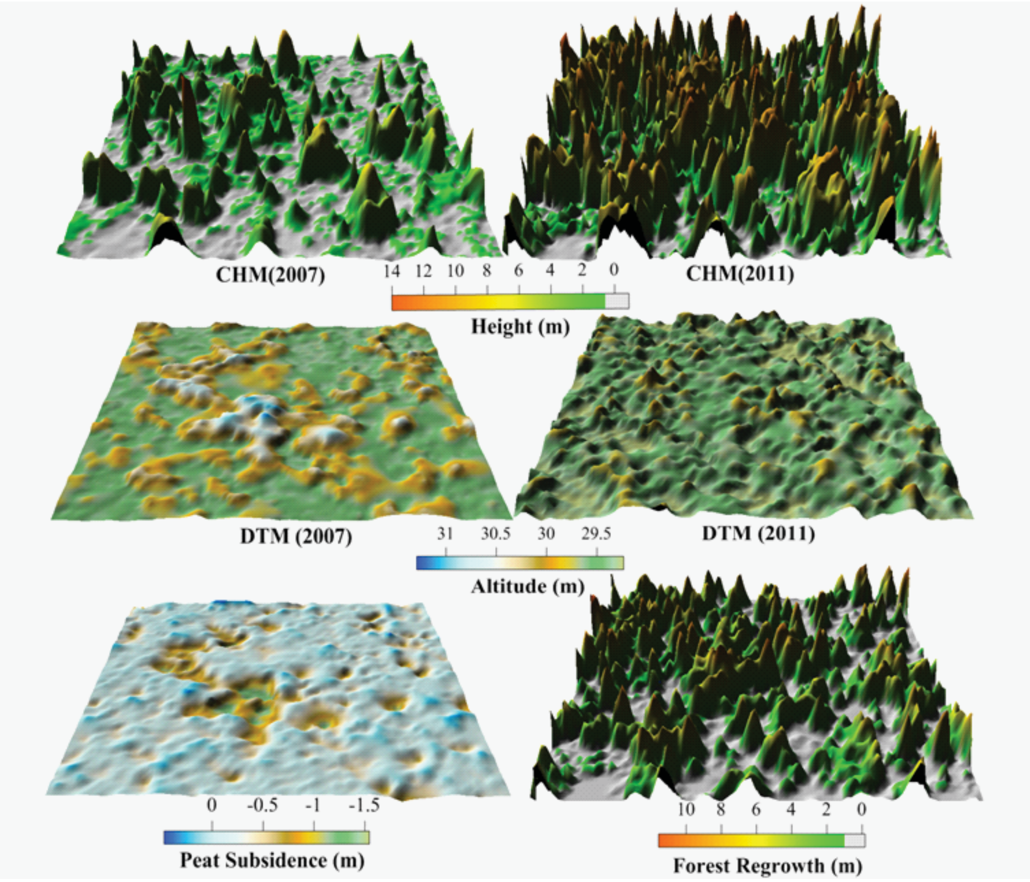

Figure 8. DTM and CHM of a sample plot for 2007 and 2011 located at a burned scar area inside the Sabangau National. Subsidence 2007 and 2011, left; regrowth 2007 and 2011, right.

Hooijer et al. (2012) reported that the subsidence rate is higher at initial stage of peat drainage and it decreases with time. The drainage of the peat cause a lowering of the water table that lead to subsidence by compaction due to peat shrinkage since peat is mostly composed by water (up to 80%, cf. Yule et al., 2010). After, oxidation may become the main contributor once the peat bulk density (mass of peat soil per unit volume) has reached certain saturation threshold. Large accumulated subsidence values were found at the dome plateau at Mawas km238 (Fig. 7b) where a drainage channel is present. Relationships between peat dome slope versus subsidence and forest regrowth could be established only at Sabangau site. At this site, low regrowth and low subsidence could be associated at steepest slope with certain uncertainty (Table 3).

However, the subsidence values for the selected transect (Table 4, Fig. 7) are higher than those observed by Jauhiainen et al. (2012) and Hooijer et al. (2012) analyzing degraded peatlands of Sumatra that were converted into oil palm and Acacia spp. plantations. Although peat characteristics and disturbance history might differ among sites, the changes reported here may also be influenced by the residual error caused by the lower point density and possible classification errors besides a vertical accuracy of 0.15m from the LiDAR system in both surveys. It is also important to mention that the four years period analyzed with LiDAR data did not encompass the period in which the drainage channels were constructed neither the forest log had started. However, the results showed a strong influence of forest disturbance on subsidence.

The forest regrowth varies from 1.5m to 3.1m during the four years period (Table 4). Mawas km228 showed the lowest forest regrowth due to the more pristine nature of the PSF. Whereas Mawas km238 and Sabangau accounted for the highest regrowth rates showing a high resilience of the PSF. Although the regrowth analysis is restricted to few sample plots, there were areas in with negative regrowth due to the deforestation of small patches (results not shown). At Sabangau partial toppling of trees were often observe during the field survey. This may be related by wind storms coupled with drainage of the peat and could be one reason for the reduced regrowth and small negative differences at the CHM at Mawas km228 (Fig. 7a). Thus, artifacts due to differences in the point density in both surveys cannot be neglected. Finally, there was no relationship between forest regrowth and peat subsidence.

Fig. 8 shows the bi-temporal DTM and CHM for a sample plot located at the burned scar at Sabangau transect (cf. Figs. 1, 3, 4, 6). Forest regrowth at this site depends both on the characteristics of the ecosystem and specifically on the fire intensity and its recurrence (Hoscilo et al., 2011). Few isolated trees and several small bushes, most probably sedges and ferns bogs that are found in such environments, can be interpreted from the CHM in 2007 (Fig. 9a) indicating a widespread tree dieback by fires during the El Niño event in 1997 (Page et al., 2002, Usup et al., 2004). At the Landsat image acquired in August 20, 2001 this burned site showed high red and low NIR values due to the large proportions of non-photosynthetic proportions of vegetation. Fire recurrences were also reported in Kalimantan in 2002, 2004, 2006 and 2009, however were not evident at Sabangau test site by analysing the Landsat images. The red response tends to decrease from August 20, 2001 to August 5, 2007 and then to June 13, 2011 while NIR increase as more photosynthetic proportions of vegetation is present (Liesenberg et al., 2010).

A relative regrowth of the PSF is noticed after a four years period acquisition between the LiDAR surveys (Fig. 7). Several hollows are observed at the bi-temporal DTMs (Fig. 8) and still remain uncovered by vegetation. This is most probably due to strong fire intensity that builds pools where the water is frequently accumulated over the year limiting therefore the vegetation regrowth. The spatial distribution of the hollows can be identified by a subset of the aerial Ortho-photos and in-situ photos (Fig. 9). The area also registers the lowest AGB, TBA, CC and PAI.

(A) (B)

Figure 9. Ortho-photo from a Hasselblad camera showing the proportions of green and non-photosynthetic vegetation within a burned scar area at the Sabangau National Park (A). In-situ ground photos of the same regeneration area (B).

Implications for the Ecology and Management of Peatlands

The most striking observation from this study is that tree canopy height appears to be closely related to peat dome slope in less disturbed PSF. Undisturbed PSF with limited or no damage are rare in Southeast Asia (Miettinen and Liew, 2010). The role of conservation units in this endangered environment is of extreme importance as reported by Hoscilo et al. (2011). The PSF degradation by drainage, forest logging and hunting affects not only the tree structure diversity, its function and the litter accumulation on the peat surface that provides hydrological regulation under natural conditions. It also affects the interdependence of trees; water table level and peat floor itself due to the lack of surface resistance (cf. Yale 2010, Dommain et al., 2010).

The analysis hereby should be understood as a case study and should highlight in which degree canopy tree height might be related with peat dome slope achieved from remote sensing techniques using airborne LiDAR data. While results would certainly differ in detail for other tropical peatland sites due to peat dome characteristics (Anderson 1983, Brady 1997) and previous land use disturbance history, the results highlighted here are of general importance for further management of this endangered ecosystem. The effectiveness of conservation units in endangered PSF could be evaluated with LiDAR measurements.

With frequent LiDAR measurements, critical areas could be rapidly being identified and adequately protected enabling counteractions of restoration and management. Thus, forest policy could undertake counteractions in areas where illegal forest logging and hunting are still being practice, as for example at Mawas km238 and Sabangau transects. This is valid mainly in steep dome slope areas since they represent an important hydrological function to the peat dome.

Conclusive Remarks

A clear dependence between peat dome slope and tree height with was confirmed with LiDAR data. With increasing peat dome slope at the selected transects, the relation between CHM height got closer. However, it was strongly dependent on the previous degradation history.

Accumulated peat subsidence varies significantly ranging in average from 0.15 to 0.50m. Highest values were found close to drainage channels, at the peat dome plateau and previous burned areas. PSF showed high resilience in degraded PSF by forest log. Forest regrowth varies from 1.5 to 3.1m during the four years period.

The results lead to the conclusion that degraded PSF might result in dramatic changes to the eco-hydrological function of the peat domes requiring management counteractions in this endangered ecosystem. The effect of forest logging activities on PSF environments and their effects on climate change should also be investigated and confirm whether this disturbance may increase the flux of CO2. Since peat swamp degradation may enhance peat respiration more than net primary production, more and more areas will become carbon sources rather than carbon sinks, which may have an impact on climate change.

Understanding tree height variations associated with slope gradients is important once we consider that the last remnants of PSF are located in Kalimantan that is suffering high rates of deforestation. In the coming years, as indicated by political support for REDD long-term monitoring of the peat domes will be crucial to quantify changes in carbon stocks of the peat swamp forest, and to evaluate forest growth response to climate and land use change in which LiDAR measurements can play an important task.

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References

Anderson, J.A.R., 1964. The structure and development of the peat swamps of Sarawak and Brunei. The Journal of Tropical Geography, 18, 7-16.

Anderson, J.A.R., 1983. The tropical peat swamps of western Malesia. In: Gore, A.J.P. (ed.) Mires: Swamps, Bogs, Fen and Moor. Ecosystems of the World 4B, Elsevier, Amsterdam, 181-199.

Ali, M., Taylor, D., Inubushi, K., 2006. Effects of environmental variations on CO2 efflux from tropical peatland in eastern Sumatra. Wetlands, 26(2), 612-618.

Asner, G.P., Mascaro, J., Muller-Landau, H.C., Vieilledent, G., Vaudry, R., Rasamoelina, M., Hall, J., van Breugel, M., 2012. A universal airborne LiDAR approach for tropical forest carbon mapping. Oecologia 168(4), 1147-1160.

Bakker, T.W.M., 1992. The shape of bogs from a hydrological point of view. International Peat Journal, 4, 47-54.

Boehm, H.-D.V., Siegert, F., 2004. The impact of logging on land use change in Central Kalimantan, Indonesia. International Peat Journal, 12, 3-10.

Boehm, H.-D.V., Rieley, J.O., Limin, S., Frank, J., Syafrudin M., 2007. Successful Helicopter Flight Trials with Airborne Laser Scanning Technology to measure PSF height and Peat domes in Central Kalimantan. In: International Symposium, Workshop and Seminar on Tropical Peatland, "Carbon - Climate - Human Interactions - Carbon Pools, Fire, Mitigation, Restoration and Wise Use", 27 - 31 August, Yogyakarta, Indonesia.

Boehm, H.-D.V., Frank, J., 2008. Peat Dome Measurements in Tropical Peatlands of Central Kalimantan with a high-resolution Airborne Laser Scanner to achieve Digital Elevation Models. In: Proceedings of 13th International Peat Congress, 8-13 June 2008, Tullamore, Ireland, Section 5: Tropical Peatlands.

Boehm, H.-D.V., Liesenberg, V. and Frank, J. 2010. Relating tree height variations to peat dome slope in Central Kalimantan, Indonesia using small-footprint airborne LiDAR data, in Proc. 10th Int. Conf. LiDAR Applications for Assessing Forest Ecosystems.—SilviLaser, Freiburg, 2010, pp.216.–228.

Boehm, H.-D.V., Liesenberg, V., Frank, J., Limin, S., 2012. Multi-temporal Helicopter LiDAR- and RGB-Survey in August 2007 and 2011 over Central Kalimantan's Peatland. In Proceedings of 3rd International Workshop on Wild Fire and Carbon Management in Peat-Forest in Indonesia, 22-24 September 2011, Palangkra Raya, Indonesia.

Boehm, H.-D.V., Liesenberg, V., Limin, S., 2013. Multi-Temporal Airborne LiDAR-Survey and Field Measurements of Tropical Peat Swamp Forest to Monitor Changes. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, VOL. 6, No. 3, June 2013, 1524-1530

Brady, M.A., 1997. Effects of vegetation changes on organic matter dynamics in three coastal peat deposits in Sumatra, Indonesia. In: Rieley, J.O., Page, S.E. (eds.). Biodiversity and Sustainability of Tropical Peatlands, Samara Publishing, Cardigan, UK, 113-134.

Brown, S., 1997. Estimating Biomass and Biomass Change of Tropical Forests: a primer (FAO Forestry Paper-134), FAO, United Nations, Rome.

Bruenig, E.F., 1990. Oligotrophic forested wetlands in Borneo. In: Lugo, A.E., Brinson, M., Brown, S. (eds.). Forested Wetlands. Ecosystems of the World 15, Elsevier, Amsterdam, 299-334.

Chave, J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Folster, H., Fromard, F., Higuchi, N., Kira, T., Lescure, J.P., Nelson, B.W., Ogawa, H., Pulg, H., Riera, B., Yamakura, T., 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologica, 145, 87–99.

Chimner, R.A., Ewel, K.C., 2005. A tropical freshwater wetland: II. Production, decomposition, and peat formation. Wetlands Ecology and Management, 13(6), 671-684.

Couwenberg, J., Joosten, H., 1999. Pools as missing links: the role of nothing in the being of mires. In: Standen, V.J., Tallis J.H., Meade, R. (eds.). Patterned Mires and Mire Pools - Origin and Development; Flora and Fauna. British Ecological Society, London, 87-102.

Couwenberg, J., Joosten, H., 2005. Self organisation in raised bog patterning: the origin of microtope zonation and mesotope diversity. Journal of Ecology, 93(6), 1238–1248.

Couwenberg, J., Dommain, R., Joosten, H., 2010. Greenhouse gas fluxes from tropical peatlands in south-east Asia. Global Change Biology, 16(6), 1715-1732.

Crook, M.J., Ennos, A.R., Banks, J.R., 1997. The function of buttress roots: a comparative study of the anchorage systems of buttressed (Aglaia and Nephelium ramboutan species) and nonbuttressed (Mallotus wrayi) tropical trees. Journal of Experimental Botany, 48(9), 1703-1716.

Dommain, R., Couwenberg, J., Joosten H., 2010. Hydrological self-regulation of domed peatlands in south-east Asia and consequences for conservation and restoration. Mires and Peat, 6(5), 1-17.

Dommain, R., Couwenberg, J., Joosten, H., 2011. Development and carbon sequestration of tropical peat domes in south-east Asia: links to postglacial sea-level changes and Holocene climate variability. Quaternary Science Reviews 30(7-8), 999-1010.

Esterle, J.S., Ferm, J.C., 1994. Spatial variability in modern tropical peat deposits from Sarawak, Malaysia and Sumatra, Indonesia: analogues for coal. International Journal of Coal Geology, 26(1-2), 1-41.

Gibbs, H.K., Brown, S., Nilesand, J.O., Foley, J.A., 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environmental Research Letters 2(4), 1-13.

Hajnsek, I., Kugler, F., Lee, S.K., Papathanassiou, K.P., 2009. Tropical-forest-parameter estimation by means of Pol-InSAR: The INDREX-II campaign. IEEE Transactions on Geoscience and Remote Sensing, 47(2), 481-493.

Hamard, M., Cheyne, S.M., Nijman, V., 2009. Vegetation correlates of Gibbon Density in the Peat-Swamp Forest of the Sabangau Catchment, Central Kalimantan, Indonesia. American Journal of Primatology, 72(7), 607-616.

Harrison M.E., Cheyne S.M., Darma F., Ribowo D.A., Limin S.H., Struebig M.J., 2011. Hunting of flying foxes and perception of disease risk across Central Kalimantan, Indonesia. Biological Conservation. 144(10), 2441-2449.

Herwitz, S.R., 1988. Buttresses of tropical rainforest trees influence hillslope processes. Earth Surface Processes and Landforms, 13(6), 563-567.

Hirano, T., Segah, H., Harada, T., Limin, S., June, T., Hirata, R., Osaki, M., 2007. Carbon dioxide balance of a tropical peat swamp forest in Kalimantan, Indonesia, Global Change Biology, 13(2), 412-425.

Hoscilo, A.C., Page, S.E., Tansey, K.J., Rieley, J.O., 2011. Effect of repeated fires on land-cover change on peatland in southern Central Kalimantan, Indonesia, from 1973 to 2005. International Journal of Wildland Fire 20(4), 578-588.

Hooijer, A., 2005. Hydrology of tropical wetland forests: recent research results from Sarawak peat swamps. In: Bonell, M., Bruijnzeel, L.A. (eds.). Forest, Water and People in the Humid Tropics. Cambridge University Press, Cambridge, 447–461.

Hooijer A., Page S., Jauhiainen J., Lee W.A., Lu X.X., Idris A., Anshari, G., 2012. Subsidence and carbon loss in drained tropical peatlands. Biogeosciences, 9(3), 1053-1071.

Hyyppä, J., Kelle, O., Lehikoinen, M., Inkinen, M., 2001. A segmentation-based method to retrieve stem volume estimates from 3-D tree height models produced by laser scanners. IEEE Transactions on Geoscience and Remote Sensing, 39(5), 969-975.

Jaenicke, J. Rieley, J.O., Mott, C., Kimman, P., Siegert, F., 2008. Determination of the amount of carbon stored in Indonesia peatlands, Geoderma, 147(3-4), 151-158.

Jauhiainen, J., Takahashi, H., Heikkinen, J.E.P., Martikainen, P.J., Vasander, H., 2005. Carbon fluxes from a tropical peat swamp forest floor, Global Change Biology, 11(10), 1788-1797.

Jauhiainen J., Hooijer, A., Page, S.E., 2012. Carbon dioxide emissions from an Acacia plantation on peatland in Sumatra, Indonesia. Biogeosciences 9(2), 617-630.

Joosten, H., 1993. Denken wie ein Hochmoor: Hydrologische Selbstregulation von Hochmooren und deren Bedeutung für Wiedervernässung und Restauration (Thinking like a bog: hydrological self-regulation of raised mires and its implications for re-wetting and restoration). Telma, 23, 95–115 (in German).

Korpela I., Koskinen M., Vasander H., Holopainen M., Minkkinen K., 2009. Airborne small-footprint discrete-return LiDAR data in the assessment of boreal mire surface patterns, vegetation, and habitats. Forest Ecology and Management, 258(7), 1549-1566.

Kraus, K., Pfeifer, N., 1998. Determination of terrain models in wooded areas with airborne laser scanner data. ISPRS Journal of Photogrammetry and Remote Sensing, 53, 193-203.

Kronseder, K., Ballhorn, U., Boehm, V., Siegert, F., 2012. Above ground biomass across forest types at different degradation levels in Central Kalimantan using LiDAR data.International Journal of Applied Earth Observation and Geoinformation, 18, 37-48.

Liesenberg, V., Boehm, H-D.V., Gloaguen, R., 2010. Spectral variability and discrimination assessment in a tropical peat swamp landscape using CHRIS/PROBA data. GIScience and Remote Sensing, 47(4), 541-564.

Ludang, Y., Jaya, A., Inoue, T., 2007. Microclimate conditions of the developed peatland in Central Kalimantan. Journal of Applied Sciences, 7(18), 2604–2609.

Miettinen, J., Liew, S.C., 2010. Status of Peatland Degradation and Development in Sumatra and Kalimantan. Ambio, 39(5-6), 394-401.

Nishimua, T.B., Suzuki, E., Kohyama, T., Tsuyuzaki, S., 2007. Mortality and growth of trees in peat-swamp and heath forest in Central Kalimantan after severe drought. Plant Ecology, 188(2), 165-177.

Page, S.E., Rieley, J.O., Shotyk, Ø.W., Weiss, D., 1999. Interdependence of peat and vegetation in a tropical peat swamp forest. Philosofical Transactions of the Royal Society, London, Series B: Biological Science, 354(1391), 1885-1897.

Page, S., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jaya, A., Limin, S., 2002. The amount of carbon released from peat and forest fires in Indonesia during 1997. Nature, 420(6911), 61-65.

Page, S.E., Wust, R.A.J., Weiss, D., Rieley, J.O., Shotyk, W., Limin, S.H., 2004. A record of Late Pleistocene and Holocene carbon accumulation and climate change from an equatorial peat bog (Kalimantan, Indonesia): Implications for past, present and future carbon dynamics. Journal of Quaternary Science, 19(7), 625-635.

Page, S.E., Banks, C., 2007. Tropical peatlands: distribution, extend and carbon storage - uncertainties and knowledge gaps. Peatlands International, 2(1), 26-27.

Page, S., Hoscilo, A., Wösten, J.H.M., Jauhiainen, J., Silvius, M.J., Rieley, J., Ritzema, H.P., Tansey, K., Graham, L., Vasander, H., Limin, S., 2009. Restoration ecology of lowland tropical peatlands in Southeast Asia: Current knowledge and future research directions. Ecosystems, 12(6), 888-905.

Richter, W., 1984. A structural approach to the function of buttresses of Quararibea asterolepis. Ecology, 65(5), 1429–1435.

Sieffermann, R.G., Rieley, J.O. and Fournier, M., 1992, The lowland peat swamps of Central Kalimantan (Borneo): a complex and vulnerable ecosystem. In: Proceedings of the 2nd International Conference on Geography in the Asian Region, Yogyakarta, Indonesia. 26pp.

Sorensen, K.W., 1993. Indonesian peat swamp forests and their role as a carbon sink, Chemosphere, 27(6), 1065-1082.

Shepherd, P.A., Rieley, J.O., Page, S.E., 1997. The relationship between forest vegetation and peat characteristics in the upper catchment of Sungai Sebangau, Central Kalimantan. In: Rieley, J.O., Page, S.E. (Eds.). Biodiversity and Sustainability of Tropical Peatlands. Samara Publications, Cardigan, United Kingdom, pp. 191-210.

Shimamura, T., Momose, K., 2005. Organic matter dynamics control plants species coexistence in a tropical peat swamp forest. Proceedings of the Royal Society B, 272(1571), 1503-1510.

Shimamura, T., Momose, K., Kobayashi, S., 2006. A comparison of sites suitable for the seedling establishment of two co-occurring species, Swintonia glauca and Stemonurus scorpoides, in a tropical peat swamp forest. Ecological Research, 21(5), 759-767.

Shimamura, T., Momose, K., 2007. Reciprocal interactions between carbon storage function and plant species diversity in a tropical peat swamp forest. Asian and African Area Studies, 6(2), 279-296.

Takahashi, H., Yonetani, Y., 1997. Studies on microclimate and hydrology of peat swamp forest in Central Kalimantan, Indonesia. In: Rieley, J.O., Page, S.E. (Eds.). Biodiversity and Sustainability of Tropical Peatlands. Samara Publications, Cardigan, United Kingdom, pp. 179-187.

Tawaraya, K., Takaya, Y., Turjaman, M., Tuah, S.J., Limin, S.H., Tamai, Y., Cha, J.Y., Wagatsuma, T., Osaki, M., 2003. Arbuscular mycorrhizal colonization of tree species grown in peat swamp forests of Central Kalimantan, Indonesia. Forest Ecology and Management, 182(1-3), 381-386.

Usup, A., Hashimoto, Y., Takahashi, H., Hayasaka, H., 2004. Combustion and thermal characteristics of peat fire in tropical peatland in Central Kalimantan, Indonesia. Tropics, 14, 1-19.

Wösten, J.H.M., Clymans, E., Page, S.E., Rieley, J.O., Limim, S.H., 2003. Peat-water interrelationships in a tropical peatland ecosystem in Southeast Asia. Catena, 73(2), 212-224.

Yamada, I., 1997. Tropical Rain Forests of Southeast Asia: a Forest Ecologist's View. University of Hawai'i Press, Honolulu, 392pp.

Yonebayashi, K., Okazaki, M., Kaneko, N., Funakawa, S., 1997. Tropical peatland soil ecosystems in Southeast Asia: their characterisation and sustainable utilisation. In: Rieley, J.O., Page, S.E. (eds.). Biodiversity and Sustainability of Tropical Peatlands, Samara Publishing, Cardigan, UK, 103–134.

Yule, C.M., 2010. Loss of biodiversity and ecosystem functioning in Indo-Malayan peat swamp forests. Biodiversity and Conservation, 19(2), 393-409.

Use of Organic Matter to Reduce Greenhouse Gases Emission and Increase Peat Soil Productivity

Dedi Nursyamsi and Eni Maftuah
Indonesian Agency for Agricultural Research and Development (IAARD)

E-mail: ddnursyamsi@yahoo.com

Peatlands are one of the marginal lands that can be developed as a potentially productive agricultural area. Utilization of peatlands for agriculture has been done since long time ago. But we have to be aware that their use has environmental risks, such as: land degradation, greenhouse gases (GHGs) emissions, and decrease of land productivity. Therefore proper management of peatlands is needed in their use for agriculture. Use of organic matter as ameliorant is one of the success keys in management of peatlands . The research results showed that use of organic matter as ameliorant in peat soil reduced GHG emissions, improved soil productivity, and increased plant yield. Organic matter of rice husk biochar and animal manure reduced CO2 and CH4 fluxes at peat soil of both upland and lowland condition. The organic matter could improve soil pH as well as become source of nutrients, such as N, P, K, Ca, and Mg. Quality of organic matter significantly affected ability of organic matter in reducing GHG emissions and increasing peat soil productivity. Thus, the proper selection and management of organic matter are very important in reducing GHG emissions and improving peat soil productivity.

Keywords : GHGs emission, Organic matter, Peat soil, Productivity

INTRODUCTION

Indonesia is one country that has a fairly extensive peatlands, which is about 14.91 million hectares, spread over the large islands, such as Borneo, Sumatera, Papua, as well as in several smaller islands (BBSDLP, 2011). Peatland has great potential to be developed as an area of development of productive agriculture. But, it is generally low productivity of peatlands due to face many obstacles. Peatland development faces several constraints, such as: low soil fertility, water problems, and subsidence. Many technologies are applied to overcome these obstacles. Even so the application needs to be holistic and participatory approach with considering conservation of peatland resources (Alihamsyah, 2002 in Sarwani and Noor , 2004).

Implementation of environment-friendly farming systems on peatland is very necessary. The farming systems base on technologies which increase sustainable productivity, economically profitable, socially and culturally acceptable and do not damage or diminish function of environtment. Implementation of the farming systems in Central Kalimantan and West Kalimantan peat soil showed that it increased agricultural production, reduced environment damage and socially acceptable (Figure 1). Environmental effects caused by mismanagement of peatland were among others: very fast degradation of peatlands, increase of GHG emissions, and land subsidence due to mass loss.

Exploitation of peatland will be successful if implemented with proper and accurate approach and technology. Appropriate land management must be in accordance with peat soil characteristics, so that it becomes productive, sustainable, and environmentally friendly. One of efforts to increase its productivity is through addition of ameliorant. Ameliorant is a material added to soil to improve root environment for plant growth (Attiken et al., 1998). The ameliorant can suply several nutrients, reduce soil acidity and bind leached cations by flushing water (Supriyo, 2006). Additionally, ameliorant of mineral soil material which contains several polyvalent cations (Fe, Mn, Zn, etc.) can bind residual organic acids to produce a more stable compound, so that reduce level of peat soil decomposition as well as decrease greenhouse gas emissions.

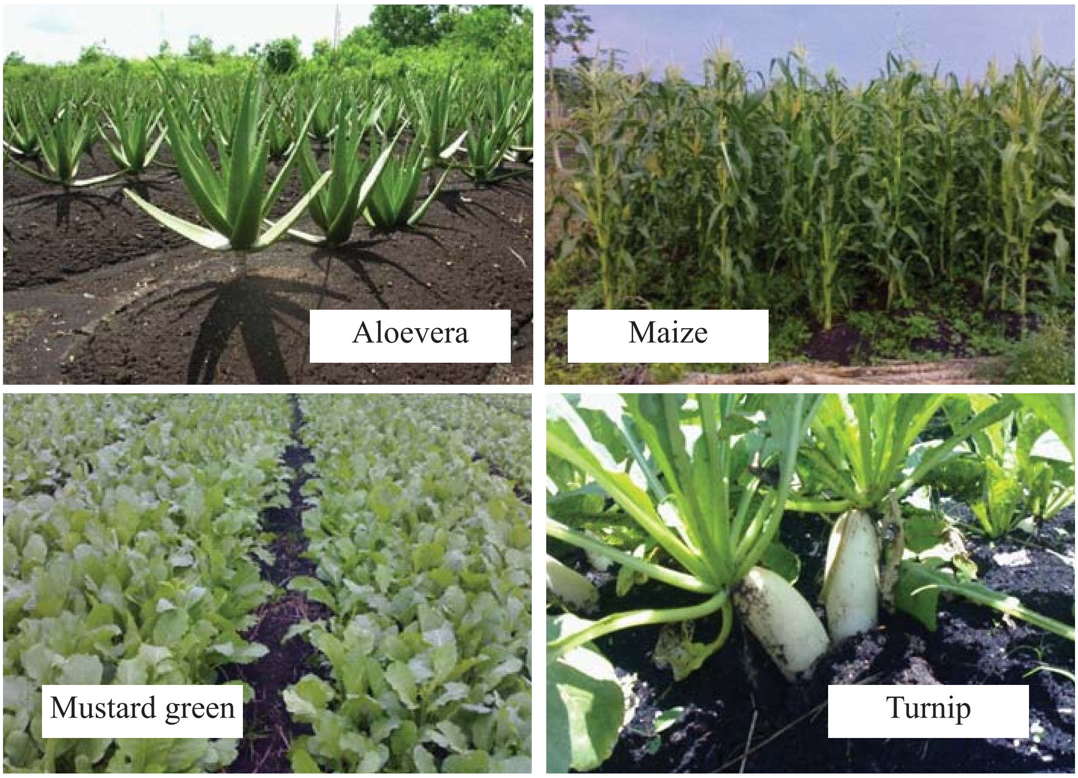


Figure 1. Performance of plants in peat soils with appropriate management

Use of ameliorants is one of important aspect in sustainable peatland management. Ameliorant material can come from a lot of sources of both organic and inorganic matter, among other: organic compost, animal manure, fish meal or animal and fishery waste. Inorganic ameliorant which is widely investigated is lime, mineral soil, volcanic ash, sea mud, and mud river. Organic materials have high potential for ameliorant in peatlands, but the material selection should be done carefully in order to get high effectiveness. Appropriate organic ameliorant do not only increase soil productivity, but also reduce greenhouse gases emission in peatlands.

This paper talk about general characteristics of peat soil, potency of organic matter as ameliorant in peatlands, as well as effect of organic ameliorant on GHG emissions and peatland productivity.

PEAT SOIL CHARACTERISTICS

Characteristics of peat soil are largely depending on composition of parent materials (such as type and variety of plants) and condition of its forming (climate, hydrology, topography, and time). Peatforming factors are influence each other giving specific characteristics of the peat soil.

One of the important characteristics of peat soil is ability to bind water molecule in a very large amount (hydrophilic). This condition is associated with organic matter content of peat soil is very high (exceeding 70 %) and porosity is also high (exceeding 80 %). Peat sapric had water holding capacity less than 450 %, hemic had 450-850, and fibric had more than 850 % (Notohadiprawiro, 1997). Hardjowigeno (1997) also stated that water holding capacity of peat soil was very high, peat fibric reached 4.5-20 times of dry weight while peat saprik reached 4.5 to 8.5 times of the dry weight. Peat soil, however, has an irreversible drying nature, since drying for a long time, the ability to bind water drops significantly (hydrophobic).

Other specific physical properties of peat soil is very high porosity, range between 80-95 % and the volume-weight is very low, range between 0.05-0.25 g cm-1. Porosity is related to degree of peat soil decomposition, where peat with high decomposition rate (sapric) has lower porosity than low decomposition rate of the peat soil (fibric). Fibric peat soil porosity ranged about 88.0 % while sapric peat soil ranged about 82.60% (Supriyo and Maas, 2005).

Chemical properties of peat soils include high soil acidity (low soil pH or soil pH < 5) which is caused by decomposition of the soil resulting large amount of organic acids. The organic acids are usually dominated by fulvic and humic acids (Widjaja-Adhi, 1988; Rachim, 1995). They contributed significantly to the low soil pH (Charman, 2002). Decomposed organic materials have reactive functional groups including carboxylic (-COOH) and phenolic (C6H4OH) acids which dominated exchange complex of soil coloidal. The organic acids were weak acid that could be dissociated and produce H+ ions in large quantities. The low soil pH affected availability of nutrients for plant growth, such as: P , K and Ca and a number of micro elements (Marschner, 1986).

Peat lands in Indonesia have a higher lignin content than peat in temperate climates. Tropical peat-forming materials are generally derived from woody trees that have a high lignin content, while peat in temperate countries are formed from finer materials, such as grass and moss that have high levels of cellulose and hemicellulose. The lignin will be decomposed resulting soluble organic compounds, phenolic acid. Phenolic acids can directly influence biochemical and physiological processes of plants as well as availability of nutrients in the soil.

Cation exchange capacity (CEC) of peat soil was very high, ranging between 100-300 me/100g of absolute dry weight (Hartatik and Suriadikarta, 2006). The high CEC value was caused by negative charge of pH-dependent charge largely derived from carboxylic and phenolic groups. Carboxylate groups contributed to CEC by 10-30 % (Charman, 2002), while derivates of lignin fraction were the largest contributor to the CEC of 64 -74 % (Driessen, 1979 in Hartatik and Suriadikarta, 2006). The high CEC value caused the soil required a number of ameliorant to reach equilibrium. Since bulk density of peat soil was very low (0.15 to 0.20 g cm-3), thus determination of ameliorant dose per unit area should be multiplied by a correction factor of 0.15 to 0.20 (Maas, 1997).

Peat soil fertility depends on the soil under the peat layer, but generally peat soil is not fertile. The soil fertility also depends on typology of peatlands, where swampy peat generally is more fertile than that of tidal. The swampy peat had higher pH, lower organic C content, and higher concentration of bases (Ca, Mg and K) (Noor et al., 2005; Noor et al., 2007). In the swampy area, the nutrients did not lose out from the system due to physiographic of swampy lands is basin form. Nutrient enrichment due to deposition process during water flood also occurred periodically in this area. These reasons caused the peat soil in swampy lands was better than that in tidal land.

Based on peat formation process, peat soil can be divided into topogen and ombrogen. The topogen peat formation is caused by topography or basin condition, so it is usually more fertile than ombrogen because of influence of mineral soil. While the peat which grows on topogen peat is called as ombrogen peat where its formation is influenced by rainfall (Agus and Subiksa, 2008).

Ash content also could be used as indicator of peat soil fertility (Kurnain, 2005). Ash content of oligotrophic peat soils is generally less than 1 %, except that of burned peat or intensively cultivated peat could reach about 2-4 % (Adi Jaya et al., 2001). The thicker peat the lower content of ashes and also the lower content of bases. The low content of bases on ombrogen peat is direcly affected by rain water which no bases content at formation processes. In addition, leaching nutrients processes to outside of the system during formation processes of peat also caused low content of bases on ombrogen peat soil.

The availability of micro elements in peat soil is generally low. This is partly because of continuous leaching process as well as chelation of carboxylic and phenolic groups resulting complex compounds. In addition, the parent material also contain very poor organic micro nutrients. As a result, the micro elements are not available to plants growth while the peat soil is more stable (Table 1).

Table 1. Peat soil characteristics of Hulu Sungai Selatan District, Central Kalimantan (swampy land) and Pulang Pisau District, Central Kalimantan (tidal swampland)

Soil Characteristics	Peat soil of swampy land[1)]	Peat soil of tidal swampland[2)]
pH (1:1)	4.00	3.80
Organic C (%)	16.06	55.55
Total N (%)	0.63	0.64
Available P (ppm P_2O_5)	7.61	30.35
Total P (ppm P_2O_5)	568	-
Total K (ppm K_2O)	262	86.00
Exch. K (cmol(+)/kg)	0.66	-
Exch. Ca (cmol(+)/kg)	14.52	4.65
Exch. Mg (cmol(+)/kg)	5.30	4.46
Exch. H(cmol(+)/kg)	-	0.30
Exch. Al (cmol(+)/kg)	0.10	0.85
Exch. Fe (cmol(+)/kg)	625.60	26.43
Cu (ppm)	-	22.50
Zn (ppm)	-	170
CEC (cmol (+)/kg)	37.75	-
SO_4(cmol(+)/kg)	955	-

Source: [1)]Noor et al. (2005) and [2)]Noor et al. (2007)

POTENCY OF ORGANIC MATTER AS AMELIORANT IN PEAT SOIL

In an effort to improve peat soil fertility, farmers generally use organic matter as amelorant, such as: oash, manure, fish meal, and shrimp head (Noorginayuwati et al., 2006). Several farmers in Siantan, West Kalimantan have successfully used ameliorant at thick peat soil. They used ash from burning remains plants and weeds, manure, fish meal and shrimp head meal. The ameliorant materials contained many cations, such as: K, Ca, and Mg so that its pH was also high.

Farmers in Kalampangan, Central Kalimantan generally use local organic and inorganic materials well for a good farming, such as: use of ash, manure, and soil minerals. The ash is derived from combustion of weeds and woody peat soils. To get as much as one kilogram of ash needed as much as organic material about 10-12.5 kg. Meanwhile, farmers used the ash about 4 t ha-1, so that the organic material was required around 40-50 t ha-1. Farmers in Kalampangan also use ash and manure for feeding vegetable crops as much as twice in a year. Utilization of weeds and wood ash at peat soil continuously can affect sustainability of peat and an increase of CO2 emissions and can be a source of peat fires, thereby reducing carbon stocks in peatlands. That is why, efforts to use alternative materials ameliorant except ash is needed to be done in order to maintain sustainable peat soil and prevent an increasing CO2 emission.

Organic materials do not only have high potency as a source of ameliorant, but also are a major source of organic fertilizer. Organic fertilizers are fertilizers that are largely or entirely composed of organic materials derived from remains of plants and animals that have been treated through a solid or liquid form which is used to supply organic matter, improve soil physical, chemical and biological properties (Ministry of Agricultural Regulation No. 2 of 2006). Criteria of a material which can be used as organic fertilizer is to have a total N > 6 %, P > 2 %, and K content > 1 % (Suriadikarta and Setyorini, 2006).

Farmers in West Kalimantan usually use organic materials, such as: fish flour, shrimp head flour, cattle manure, and chicken manure. Shrimp head flour contained N (3.08 %), P (0.75 %), K (0.82 %), Ca (2.41%), Mg (0.18 %), while fish flour contained N (2.35 %), P (0.57 %), K (0.82 %), Ca (0.73 %), Mg (0.13 %) (Noorginayuwati et al., 2007). Rice husk contained a lot of K and other base cations, thus it was potentially used as a source of nutrients and soil ameliorant substituting peat ash. Biochar can be used as an ameliorant material in peatlands. Biochar had a higher pH than most other ameliorants materials (Table 2). Although Ca content in biochar was lower than that in chicken manure, but it was higher than that in purun tikus grass and agricultural weeds. The critical value of C/N for occurrence of decomposition and mineralization was less than 25 or 30 (Handayanto, 1995). It mean that agricultural weeds and purun tikus grass were more stable than animal manure and biochar because C/N value were more than 30. Agricultural weeds had good nutrient content of P, K, Ca, Mg and had pH higher than purun tikus grass had.

Animal manure has long been used by farmers to improve peat soil fertility in Kalampangan, Central Kalimantan. Farmers usually combine it with ash for cropping vegetable. Ability of animal manure to increase soil pH was limited, so its application need in large amounts, range from 2.5-10 tones ha-1 (Prastowo, 1993). Nutrient content of fresh solid cattle manure was N (1.53 %), P (0.67 %), K (0.70 %), while the content of chicken manure was N (1.50 %), P (1.97 %), K (0.68 %) (Hartatik and Widowati, 2006). Lingga (1991) reported that nutrient content of cattle manure was N (0.30 %), P2O5 (0.20 %), K2O (0.20 %), and C/N ratio 20-25 %, while the content of chicken manure was N (1.50 %), P2O5 (1.30 %), K2O (0.80 %), and C/N ratio 9-11.

Compost of purun tikus grass also effectively increased P availability in peat soil, because it contained a large amount of Fe (7.78 ppm Fe) (Damanik, 2009). The cation Fe was able to increase P holding capacity of peat soil, so that P loss through leaching decreased. At one month of composting, it had C/N ratio of 21, soil organic C content of 42.66 %, and total N of 2.33 %. The compost was not only able to increase the buffering capacity of peat soil on P, but also able to increase sorption area and constant of bonding energy so that availability of P for plant growth increased (Masganti, 2003).

In order to get more effective organic material, it needs some further treatments on the ameliorant. Management techniques include composting, setting quality of ameliorant by mixing some organic materials of different chemical composition and improving nutrients content. Ameliorant management should also consider synchronization between release of nutrients and crop requirements. This equilibrium will increase plant nutrient uptake as well as increase efficiency of inorganic fertilization.

Environmental factors, especially soil pH needs to be considered in selecting kind of ameliorant. Besides that, chemical composition and quality of ameliorant will effect on its effectiveness. Selection and dose of ameliorant depend on major problem and purposes of amelioration. Selection of appropriate ameliorant is one important key in increasing peat soil productivity and reducing GHG emissions from the soils.

Table 2. Chemical characteristics of ameliorant materials

Characteristics	Type of ameliorant			
	Biochar	Chicken manure	Agricultural weed	*Purun Tikus* grass
Organic C (%)	24.79	31.93	44.86	44.48
Total N (%)	8.01	1.64	0.94	1.18
Total P (%)	0.09	0.64	0.25	0.08
K_2O (%)	0.54	1.26	1.02	0.99
C/N (%)	3.09	19.49	47.66	37.82
CaO (%)	1.12	5.30	0.91	0.85
MgO (%)	0.15	2.32	0.26	0.19
Na(%)	0.07	1.15	1.02	0.99
Total Fe (%)	2.43	1.80	0.04	0.16
Water Content (%)	10.47	10.56	20.02	16.11
pH	8.63	7.17	4.45	4.12

Source: Balittra, 2010

EFFECT OF ORGANIC AMELIORANT ON GHGs EMISSIONS IN PEATLANDS

Use of peatlands for paddy rice may increase greenhouse gas emissions, especially methane (CH4) emission. Peat soil which is developed as an rice fields area is strongly anaerobic state due to flooded condition. Carbon compounds are decomposed by anaerobic microbe resulting methane gas where the decomposition is influenced by oxidizing and reducing soil conditions. Theoretically methane emission occurs at a strong reducing conditions (Eh < - 250 mV).

Type of ameliorant effected on greenhouse gas emissions from rice plants in peat soil at both upland and lowland conditions. The use of high quality of organic ameliorant (rice husk biochar and mature animal manure) were able to reduce CO2 fluxes in peat soils at both lowland and upland conditions (Figure 2). Similarly, both organic ameliorant were able to decrease CH4 fluxes in a peat soil at lowland and upland conditions (Figure 3). In addition, use of rice husk biochar and mature animal manure were not only able to reduce both CO2 and CH4 emission, but also able to increase rice yield better than inorganic ameliorants, such as: Pugam A, Pugam T, and mineral soil materials (Kartikawati et al., 2012).

Another study conducted in oil palm peat soil, chicken manure could suppress CO2 emissions higher than mineral soil and rice husk ash treatments. The manure application was able to reduce CO2 emissions by 26.6 % compared to control at oil palm plantations of peatland, in Muara Jambi District, Jambi Province (Susilawati et al., 2012). Research results conducted in South Kalimantan peatland showed that use of ameliorant reduced CO2 and CH4 emissions where emission reduction depended on type of ameliorant. Application of mature animal manure produced the lowest CO2 emissions or the emission was approximately 30.4 % lower than control. Besides that, rice husk biochar and animal manure also produced CH4 emissions much lower than that of control or the emission dropped 53.3 % and 52.5 % by rice husk biochar and animal manure respectively. It showed that both ameliorant were more effective to reduce greenhouse gas emissions compared to other inorganic ameliorants, such as: Pugam A, Pugam T, and mineral soil materials.

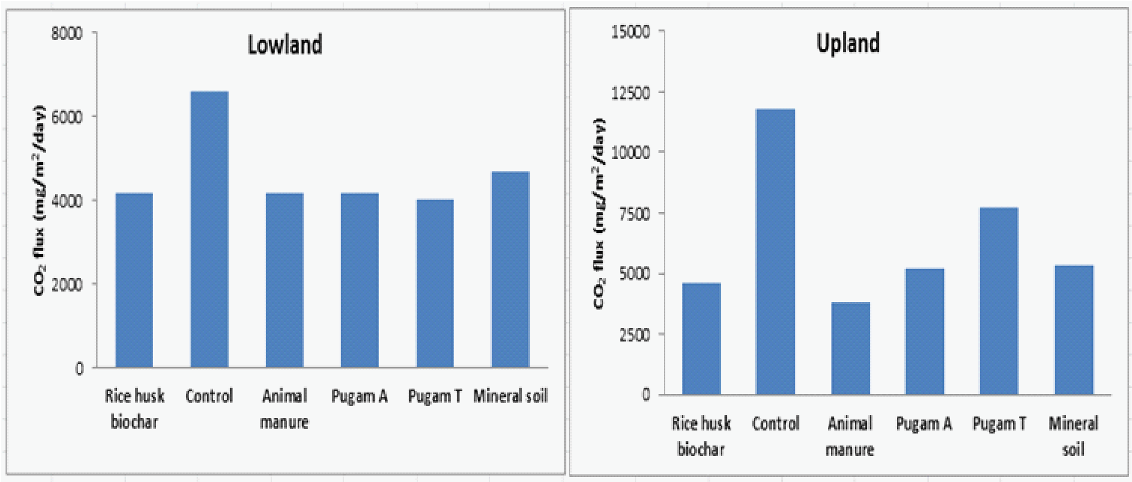


Figure 2. Effect of ameliorants on CO2 flux of lowland and upland peat soil of South Kalimantan (Kartikawati et al., 2012)

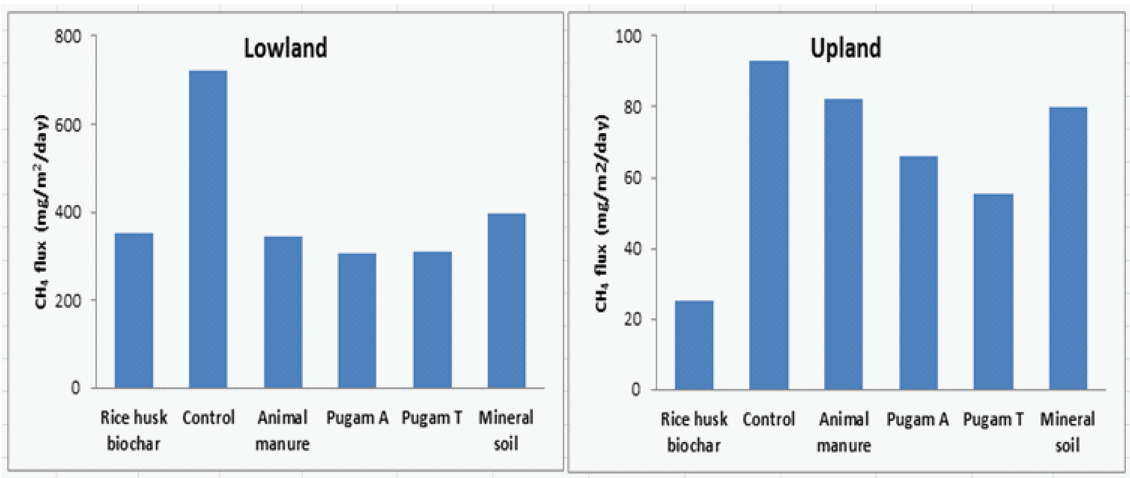


Figure 3. Effect of ameliorants on CH4 flux of lowland and upland peat soil of South Kalimantan (Kartikawati et al., 2012) Application of fresh rice which has not decomposed yet increased CH4 and N2O emissions in rice field. Jauhianinen et al. 2004 in Agus (2008) reported that methane emissions from flooded peat soil (rice field peat soil) was quite high, but at dry land or well drained land, methane emissions were very low or nothing.In relation to environmental aspects, the use of organic matter in peat soil as a ameliorant should consider quality or type of organic matter as well as level of its maturity. According to Wihardjaka (2005), methane emission in rice field treated with compost and mature animal manure was lower than that treated with green manure or fresh rice straw.

Table 3. Effect of ameliorant types on CO2 and CH4 emissions at lflooded peat soil of Landasan Ulin, South Kalimantan

Perlakuan	Gas CO_2 Emission (t ha^{-1} $season^{-1}$)	Gas CO_2 Reduction (%)	Gas CH_4 Emission (kg ha^{-1} $season^{-1}$)	Gas CH_4 Reduction (%)
Control	20.6	-	620.9	-
Rize husk biochar	18.6	9.4	289.8	53.3
Animal manure	14.3	30.4	294.6	52.5
Pugam A	14.4	29.7	300.4	51.6
Pugam T	19.2	6.5	272.7	56.1
Mineral soil	15.8	23.2	373.1	39.9

Source: Tim ICCTF, 2011

EFFECT OF ORGANIC AMELIORANT ON PEAT SOIL PROPERTIES AND PRODUCTIVITY

Amelioration and fertilization plays an important role on plant growth and production in peatlands. Peatlands are highly acidic, low macronutrients content, such as: N, P, K, Ca, and Mg, as well as micronutrients content, such as: Cu, Zn, and B. These conditions cause the peat soil requires a large amount of ameliorant to improve soil environment which is favorable for plants growth. Moreover, peat soil also needs fertilization to achieve optimum crop yields.

Type of ameliorant significantly affected peat soil chemical properties. The most effective ameliorant in improving peat soil properties was chicken manure. The chicken manure, in addition, did not only supply some nutrients of N, P, K, Ca, and Mg, but also increased soil pH from 3.39 into 3.84 (Table 4). Furthermore, the combination of animal manure with other ameliorant materials (agricultural weeds and purun tikus grass) were also able to improve peat soil fertility of Landasan Ulin, South Kalimantan. The combination did not only supply nutrients of N, P, K, and Fe, but also increased soil pH from 3:33 to became 3:58. Its combination with biochar increased soil pH higher than other treatments (Table 5). Chicken manure had a nutrient content of N, P, K , Ca, and Mg higher than agricultural weeds, biochar from coconut shells, and purun tikus grass (Table 2).

Table 4. Effect of ameliorant type on peat soil characteristics in Kalampangan, Kalteng (Maftu'ah, 2012)

Ameliorant type	NH_4 + NO_3 mg kg^{-1}	P-available mg kg^{-1}	K–exc	Ca-exc	Mg-exc	pH H_2O
			-------------cmol(+) kg^{-1}----------			
Chicken manure	108,84 a	43,31 a	2,35 a	4.09 a	3,97 a	3,84 a
Mineral soil (spodosol)	16,61 d	4,36 e	0,18 d	1,24 b	0,93 e	3,51 b
Purun tikus	71,74 b	8,76 e	0,60 c	1,24 b	0,81 e	3,39 b
Agricultural weed	39.77 c	25,30 cd	0,54 c	1,57 b	1,81 d	3,32 b
control	11,74 d	2,36 e	0,16 d	1,29 b	0,93 e	3,39 b

Table 5. Effect of ameliorants on soil characteristics of peat soil of Landasan Ulin, South Kalimantan (Balittra, 2010)

Treatments	pH H_2O	N-tot (%)	K-dd (cmol(+)/kg	P-Bray 1 (ppm P_2O_5)	Fe (ppm)
F1	3.55	1.82	3.84	51.69	165
F2	3.58	1.78	2.27	23.93	61
F3	3.50	1.82	1.26	201.95	67
Control	3.33	1.68	0.65	11.43	342

Remark : F1 (2.5 t/ha chicken manure + 2.5 t/ha *purun tikus* weed + 2.5 t/ha agriculture weeds),
F2 (1.25 t/ha chicken manure + 6.25 t/ha biochar),
F3 (0,7 t/ha chicken manure + 6.8 t/ha *purun tikus*)

Organic ameliorant did not only improve soil properties, but also increased crop yields in these soils. Combination treatment of animal manure with other ameliorants significantly increased dry weight of grain rice at peat soil of Landasan Ulin, South Kalimantan. Among the treatments tested, combination treatment of chicken manure 2.5 t/ha + purun tikus grass 2.5 t/ha + agricultural weeds 2.5 t/ha provided the highest dry grain yield (Table 5). Furthermore, other studies indicated that combination of inorganic fertilizer (urea, SP-36, and KCl) with animal manure and lime gived a better effect on water quality, soil properties, and plant growth in tides peat soil (Supriyo, et al., 2007).

Table 6. Effect of ameliorant on growth and yield of rice in peat soil of Landasan Ulin, South Kalimantan at dry season 2012 (Balittra, 2010)

Treatments	Plant hieght (cm)	Number of tiller	Plant dry weight (g/plant)	100 grain weight (g)	Yield (ton/ha)
F1	87.55 a	15.43 a	28.87 a	2.55	3.58
F2	84.98 a	13.32 ab	25.02 ab	2.80	3.42
F3	84.45 a	12.22 ab	20.53 b	2.67	3.17
Control	74.23 b	8.66 b	12.23 c	2.80	3.00

Remark : F1 (2.5 t/ha chicken manure + 2.5 t/ha *purun tikus* weed + 2.5 t/ha agriculture weeds),
F2 (1.25 t/ha chicken manure + 6.25 t/ha biochar),
F3 (0,7 t/ha chicken manure + 6.8 t/ha *purun tikus*)

CONCLUSION

Use of organic matter as ameliorant in peat soil reduced GHG emissions, improved soil productivity, and increased plant yield. Organic matter of rice husk biochar and animal manure reduced CO2 and CH4 fluxes at peat soil of both upland and lowland condition. The organic matter could improve soil pH as well as become source of nutrients, such as N, P, K, Ca, and Mg. Quality of organic matter significantly affected ability of organic matter in reducing GHG emissions and increasing peat soil productivity. Thus, the proper selection and management of organic matter are very important in reducing GHG emissions and improving peat soil productivity.

REFERENCES

Agus, F dan I.M.G. Subiksa. 2008. Lahan Gambut : potensi untuk pertanian dan aspek lingkungan. Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF). Bogor-Indonesia. 36 hlm.

Alihamsyah, T., D. Nazemi, Mukhlis, I. Khairullah, H.D. Noor, M. Sarwani, H. Sutikno, Y. Rina, F.N. Saleh dan S. Abdussamad. 2001. Empat Puluh Tahun BALITTRA : Perkembangan dan Program Penelitian Ke Depan. Balai Penelitian Tanaman Pangan Lahan Rawa. Badan Litbang Pertanian. Banjarbaru.

BBSDLP, 2011. Peta Lahan Gambut Indonesia Skala 1: 250.000 Edisi Desember 2011. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, Badan Penelitian dan Pengembangan Pertanian. 11 Halaman. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor.

Adi Jaya., J.O Rieley., T. Artiningsih., Y. Sulistiyanto and Y. Jagau 2001, Utilization of deep tropical peatland for agriculture in Central Kalimantan. Dalam : Rieley, J.O & S.E. Page (Eds) Jakarta Symposium Proceeding on Peatlands for Natural Resources Function and Sustainable Management, Jakarta. Hal. 125 – 131.

Attiken, W.P., P.W. Moody and T. Dickson, 1998. Field amelioration of acid soil in south – east Queenland. I. Effect of amendments on soil properties Australian. J. Agric. Res. 49 (4);627– 638.

Balittra, 2010. Laporan Program Insentif Riset Terapan (Ristek). Balai Penelitian Pertanian Lahan Rawa Banjarbaru.

Charman, D., 2002. Peatlands and Environmental Change. Jhon Wiley & Sons. Ltd. England.

Damanik, Z. 2009. Karakteristik jerapan fosfat gambut tropika yang diberi , kompos purun tikus. Makalah Seminar HITI. Yogyakarta 20-22 November 2009.

Hardjowigeno,S.1997. Pemanfaatan gambut wawasan lingknagan. Alami 2(1):3-6.

Hartatik, W. dan D.A. Suriadikarta, 2006. Teknologi Pengelolaan Hara Lahan Gambut. dalam Karakteristik dan Pengelolaan Lahan Rawa, I. Las (eds). Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor.

Kartikawati R., D. Nursyamsi, P. Setyanto, S. Nurzakiah, 2012. Peranan amelioran dalam mitigasi emisi GRK (CH4 dan CO2) pada land use sawah di tanah gambut ds. Landasan Ulin, Kec. Banjarbaru, Kalsel. Prosiding Seminar Nasional Pengelolaan Lahan Gambut Berkelanjutan. Badan Litbang Pertanian. Bogor 4 Mei 2012.

Kurnain, A. 2005. Dampak Kegiatan Pertanian dan Kebakaran atas Watak Gambut Ombrogen. Disertasi Program Pascasarjana Universitas Gajah Mada, Yogyakarta.

Maas, A 1997. Pengelolaan lahan gambut yang berkelanjutan dan berwawasan lingkungan. Jurnal Alami. Vol 2 (1) : 12 – 16. BPP Teknologi, Jakarta.

Maftuah, E. 2012. Ameliorasi lahan gambut terdegradasi dan pengaruhnya terhadap produksi jagung manis. Disertasi Program Pasca Sarjana, Universitas Gajah Mada, Yogyakarta.

Marschner, H., 1986. Mineral Nutrition of Hogher Plants. Acc Press. Harcourt Jovanovich Publishers. London, San Diego, New York, Berkeley, Boston, Sydney, Tokyo, Toronto. 673 Halaman.

Masganti, 2003. Kajian upaya meningkatkan daya penyediaan fosfat dalam gambut oligotrofik. Disertasi. Program Pascasarjana Universitas Gadjah Mada. Yogyakarta. 350 halaman.

Noor, M., M. Alwi dan Raihan., 2005. Teknologi Peningkatan Produktivitas Lahan Gambut. Laporan Akhir. Balai Penelitian Pertanian Lahan Rawa. Banjarbaru.

Noor, M., A. Supriyo dan Y. Lestari, 2007. Teknologi Peningkatan Produktiitas dan Konservasi Lahan Gambut. Laporan Akhir. Balai Penelitian Pertanian Lahan Rawa (Balittra). Badan Litbang Pertanian. Banjarbaru.

Noorginayuwati, A. Rafieq, Y. Rina, M. Noor dan A. Jumberi. 2006. Penggalian Kearifan Lokal Petani untuk Pengembangan Lahan Gambut di Kalimantan. Laporan Akhir. Balittra. BBSDLP. Badang Litbang Pertanian. Banjarbaru

Noorginayuwati, A. Rafieq, M. Noor dan A. Jumberi. 2007. Kearifan Lokal dalam Pemanfaatan Lahan Gambut untuk Pertanian di Kalimantan. Dalam. Mukhlis. Izzuddin N., M. Noor, R.S. Simatupang (Eds) Kearifan Lokal Pertanian di Lahan Rawa. Balai Penelitian Pertanian Lahan Rawa. Banjarbaru.

Notohadiprawiro, T., 1997. Etika Pengembangan Lahan Gambut untuk Pengembangan Pertanian Tanaman Pangan. Lokakarya Pengelolaan Lingkungan dalam Pengembangan Lahan Gambut. Badan Pengendalian Dampak Lingkungan (BAPEDAL). Palangkaraya, 18 Juni 1997.

Rachim A. 1995. Penggunaan kation-kation polivalen dalam kaitannya dengan ketersediaan fosfat untuk meningkatkan produksi jagung pada tanah gambut. Disertasi. Program Pascasarjana IPB. Bogor. 268 hal.

Sarwani, M. dan M. Noor, 2004. Pengelolaan Lahan Gambut untuk Pertanian Berkelanjutan. Agroscientiae. 11, 1-8.

Supriyo, A. and Maas 2005. Leahing impact on chemical properties of different reclamation stage of ombrogenous peat. Paper Presented at International Symposium and Workshop Restoration and Wise Use of Tropical Peatland:"Problem of BiodiversityFire, Poverty and Water Management" held in Palangkarya, at Sep 21 – 24, 2005.

Supriyo, A., 2006. Dampak Penggenangan, Pengatusan dan Amelioran Terhadap Sifat Kimia dan Hasil Padi Sawah (Studi Kasus Pangkoh, Kalimantan Tengah). Disertasi. Program Pascasarjana. UGM. Yogyakarta

Supriyo, A., M. Noor dan Y. Lestari, 2007. Teknologi Peningkatan Produktiitas dan Konservasi Lahan Gambut. Laporan Akhir. Balai Penelitian Pertanian Lahan Rawa (Balittra). Banjarbaru.

Suriadikarta, D. A. dan D. Setyorini, 2006. Baku mutu pupuk organik.dalam R.D.M. Simanungkalit, D.A. Suriadikarta, R. Saraswati, D. Setyorini dan W. Hartatik (eds). Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor.

Susilawati H.L., M. Noor, T. Sopiawati, A. Pramono dan P. Setyanto. 2012. Peranan pemberian bahan organik dan dolomit terhadap emisi GRK (CO2 dan CH4) dan neraca karbon pada lahan padi sawah di tanah gambut Kalimantan Selatan. Prosiding Seminar Nasional. Pengelolaan Lahan Gambut Berkelanjutan. Bogor. 4 Mei 2012.

Tim ICCTF, 2011. Penelitian dan pengembangan teknologi pengelolaan lahan gambut berkelanjutan untuk meningkatkan sequestrasi karbon dan mitigasi gas rumah kaca: Laporan Akhir Bidang Emisi Gas Rumah Kaca.

Widjaja-Adhi, I.P.G. 1988. Masalah Tanaman Di Lahan Gambut. Makalah disajikan dalam Pertemuan Teknis Penelitian Usahatani Menunjang Transmigrasi. Cisarua, Bogor, 27–29 Februari 1988. 16 halaman.

Wihardjaka, A. 2005. Fluks Metana pada Beberapa Komponen Teknologi Sawah Tadah Hujan di Kabupaten Pati. Prosiding Seminar Nasional. Inovasi Teknologi Pengelolaan Sumberdaya Rawa dan Pengendalian Pencemaran Lingkungan. Banjarbaru, Kalsel. 5-7 Oktober 2004.

The Changes of Natural Regeneration and Surface Carbon Stock after Peat Swamp Forest Fires

Muhammad Abdul Qirom*, Tri Wira Yuwati, and Purwanto Budi Santosa
Banjarbaru Forestry Research Institute FORDA, Banjarbaru, Indonesia

* Email address: qirom_ma@yahoo.co.id

Forest fire has altered the peat swamp forest ecosystem. Most of the changes has caused negative effect to the environment. This research aimed to describe the changes in the natural regeneration and surface carbon stock after several peat swamp forest fires. This research was carried out by vegetation analysis on the 2009, 1997 and no burnt peat swamp forest. The parameter that were used namely vegetation composition on three areas and the prediction of carbon stock with general model of Brown 1997. Seedlings, saplings, poles and trees were recorded in the vegetation analysis. The result showed that peat land fires has altered the species composition, dimension, stand density and carbon stocks of peat swamp ecosystem. Generally, Gerunggang (Cratoxylon arborescens), Merapat (Combretocarpus rotundatus) and Terentang (Campnosperma sp.) were dominant species that present in the after-burnt area. The species composition has higher variability and higher species density in the area with longer fire happening. The highest carbon stock was in the no burnt area while the lowest was in the area that was burnt in 2009. This result showed that natural regeneration recovery and carbon stock increasing in the peat swamp forest could be carried out by simply prevent them from fire and effectively applied peat fire management.

INTRODUCTION

Peat swamp forest in Indonesia has devastated due to illegal logging, conversion into other land use and forest fires. Evans (1982) stated that these factors have caused the forest degradation. Moreover, the degradation has threatened the biodiversity of the peat swamp forest. Peat swamp forest of Central Kalimantan was also experienced “phenomenal degradation” due to the failure of ex mega rice project by the establishment of massive canals that led to changes of the hydrological condition of the peat swamp forest. This was worsened with forest firest that happened annually.

According to Kuijk (2008), the natural recovery of disturbed or degraded peat swamp forest and land was slow or stagnant. This paper describes the changes in natural regeneration and surface carbon stock after peat swamp forest fires at the peat swamp forest of Central Kalimantan, specifically in the Block C of ex mega rice project.

Methods

A. Research Location

This research was carried out in The Forest For Specific Purpose (KHDTK) Tumbang Nusa Central Kalimantan (Figure 1). This area is included in the peat swamp ecosystem. The peat swamp forest in this area was experiencing forest fires between 1997-2003. Thus, several parts of logged over area experienced no fires.

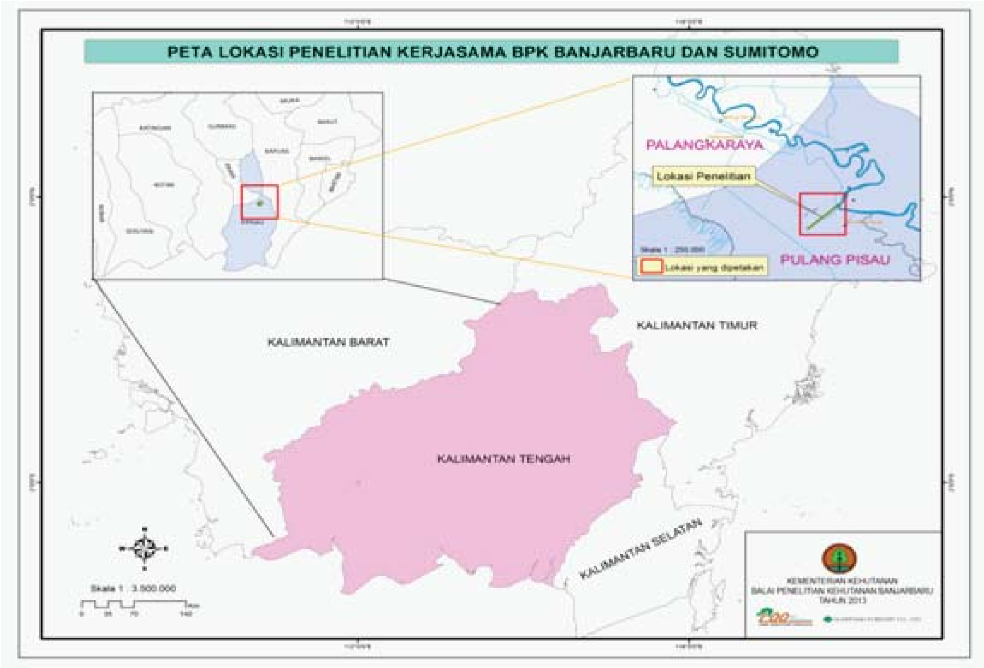


Figure 1. Research Location

B. Data Collection

B.1 Vegetation composition

The data collection was carried out in three types of sites: logged over area, area that was burnt in 2003 and area that was burnt in 1997.

The vegetation analysis was conducted for four regeneration stage: seedlings, saplings, poles and trees. The size of each plot for each regeneration stage was 2 m x 2 m for seedlings; 5m x5m for saplings; 10mx10m for poles and 20m x 20m for trees.

The data that were collected includes plants of all regeneration stages and the diameter for poles and trees. The data analysis was carried out to obtain species density, relative density, relative frequency, dominance, relative dominance and important value index.

B.2 Surface carbon stock

The prediction for carbon stock was carried out for the surface carbon. The carbon stock was measured for the poles and tree. The measurement for carbon stock was carried out by Brown formula (1997):

$$B = 0.19 D^{2.37} \qquad (1)$$

Remarks: B: biomass (kg); D: diameter at breast height (cm)

The prediction of carbon stock was conducted by conversion factor of 0.5. It means that the carbon stock was assumed 50% from its dry weight. The result of this prediction was used to predict actual carbon stock for three location (over burnt in 1997, 2003, and logged over area).

The prediction of potential of carbon stock lost in the over burnt area was formulated as follows:

$$\Delta Cs = Ci - C_{Loa} \qquad (2)$$

Remarks: ΔCs: the potential of carbon stock lost (ton/ha); C_i: the carbon stock in the location of ex burnt area: C_{Loa}: carbon stock in the logged over area

RESULT AND DISCUSSION

A. Species composition

A.1 Number and species density

The number of species in three locations was different (Figure 2). This difference was happened to all regeneration stage: seedlings, saplings, poles and trees. In seedling stage, the biggest number of species was 1997 site, LOA and 2003 site. In the sapling stage, the 1997 burnt site had the highest number of species followed by LOA and 2003 site. In the pole stage, the biggest number of species was 1997 burnt, LOA, and 2003 burnt. In the tree stage, LOA had the biggest number of species compared with 1997 and 2003 site.

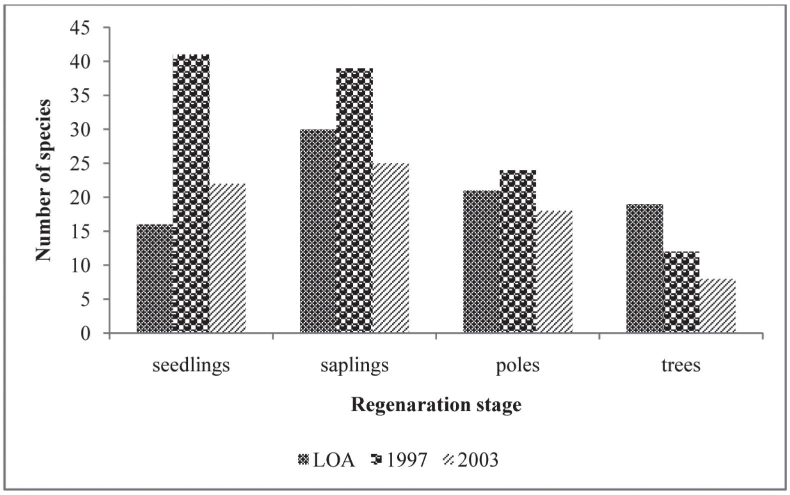


Figure 2. Species composition in several regeneration stages

The number of species for each seedling stage will decrease following the regeneration stages especially in LOA and 2003 burnt site (seedlings stage). In LOA, this condition is influenced by the tree canopy density that was so dense that seedlings could not grow well. On the contrary, the condition of the site that was burnt in 2003 was open so that the intolerant species were not able to grow. Moreover, the mother trees of these species were not available and led to regeneration disturbance for seedling stage.

The density for each regeneration stages and vegetation types were different (Table 1). Based on the species density, the forest type was normal in the forest structure for three sites. This was caused by the higher individual density the lower regeneration stage.

Table 1. The density of each regeneration stage for three sites

No	Regeneration stage	Density (individu/ha)		
		LOA	1997	2003
1	Seedlings	27058.8	37166.7	23846.2
2	Saplings	5764.7	4733.3	2646.2
3	Poles	770.6	1263.3	684.6
4	Trees	176.5	142.5	51.9

The dominance index for three sites has the value less than 1 and the highest was in the logged over area. It showed that the species composition for the three sites was not dominated by a certain species. Based on species diversity index, the three sites have diversity index less than two (Table 2). For the tree stage, the highest diversity index was on logged over area. This condition showed that species composition in that location is more stabile compared with other location.

Table 2. Dominance index and diversity in four regeneration level

Regeneration stage	Site	Index	
		Dominance	Diversity
Tree	1997	0.191	1.019
	2003	0.182	0.949
	LOA	0.106	1.381
Pole	1997	0.157	1.215
	2003	0.095	1.389
	LOA	0.109	1.382
Sapling	1997	0.070	1.316
	2003	0.062	1.288
	LOA	0.065	1.307
Seedling	1997	0.086	1.271
	2003	0.126	1.100
	LOA	0.170	0.947

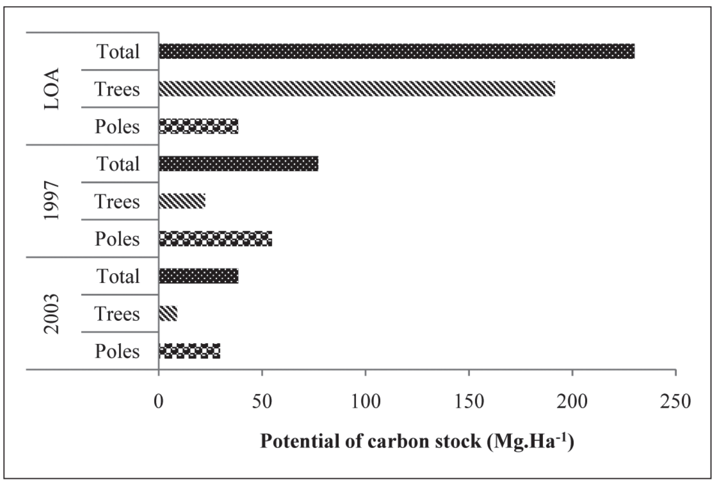
Remarks: LOA: logged over area

B. The potential of carbon stock

The potential of carbon stock on three sites ranging from 38 Mg.ha-1 - 230 Mg.ha-1. The biggest potential of carbon stock was on logged over area and the lowest was on 2003 site (Figure 3). The potential of carbon stock was influenced by the density and dimension (height and diameter) in each stand for the three sites.

In the ex burnt 1997 and 2003, the biggest potential of carbon stock was on pole stage. This condition showed that the stand composition was dominated by the pole stage compared with tree. In the two location, the potential carbon stock for pole stage was more than 75% supported the total carbon stock. This was caused by the lost or the destruction of tree stage due to forest fires happening in the location.

This condition was very different in LOA. For LOA, the biggest potential carbon stock was supported by tree stage. The carbon stock for tree stage is more than 60% of the total carbon stock (Figure 3). It showed that the stand composition for LOA had a better stand structure compared with the other two sites.



Fires have caused the disappearance of carbon stock potential in the peat swamp forest. The lost of carbon stock potential was obtained from the ratio between carbon stock potential in LOA and ex 1997 and 200 burnt sites (Figure 3). The lost of carbon stock was 150 Mg.ha-1 (Figure 4). In that location, the biggest carbon stock potential lost was in the tree stage. The biggest carbon stock lost was in 2003 site. It is believed that the stand was in the initial phase of regeneration compared with 1997 site.

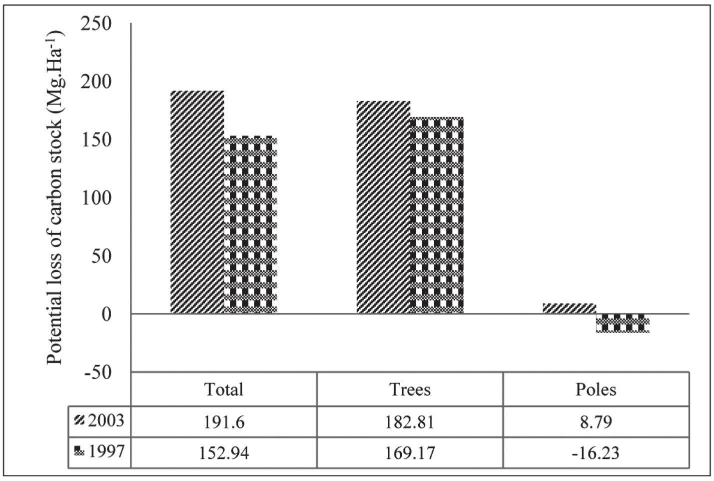


Figure 4. The lost of carbon stock potential caused by forest fire

On the 1997 site, the carbon stock potential in the form of poles was higher compared with LOA (Figure 3). This condition has led to the lower total carbon stock lost. The lost of carbon stock lost reached 16.23 Mg.Ha-1. This condition showed that natural regeneration was going very well.

Discussion

In the seedling stage, the species that commonly appeared in the three locations were tolerant species. Nevertheless, the lowest number of species was in 2003 site. It was caused by low seedling adaptation to environment. This condition was supported by the low availability of mother trees that led to natural regeneration disturbance.

The number of species was different compared with Sidiyasa (2012); Atmoko et al. (2011); and Samsoedin and Heriyanto (2010). The result of Sidiyasa (2011) showed that the number of species of Tuanan stand of Central Kalimantan was 124 tree species. Atmoko et al. (2011) recorded 31 tree species of Dipterocarpaceae at the Merapat Seed Source of Central Kalimantan. Samsoedin and Heriyanto (2010) presented 110 species in the ecosystem of mineral soils. In the mangrove ecosystem, the species variation was low (Bismark et al., 2008; Siarudin and Rahman, 2008; Heriyanto and Subiandono, 2012). It showed that habitat changes effected the species composition.

The potential of carbon stock in LOA was lower than the result of Siregar and Dharmawan (2011) at PT Sarpatim Central Kalimantan and Samsoedin et al. (2009) at Malinau, East Kalimantan. The result obtained the carbon stock of 204.9 Mg.Ha-1 (Siregar and Dharmawan, 2011) and 249,1 Mg.Ha-1 (Samsoedin et al. 2009) for surface carbon stock. Nevertheless, the differences were not high because the carbon stock potential in this research did not count for the carbon stock in litter, necromass, seedlings and saplings.

The potential of carbon stock lost caused by peat swamp forest fires was bigger than carbon stock potential in the plantation of 8 years Acacia mangium at South Kalimantan of 60 Mg.Ha-1(Qirom et al., 2012); 4 years A. Mangium at Maribaya of 31.41 Mg.Ha-1 and potential carbon stock at mangrove ecosystem of 24.56 Mg.Ha-1 (Bismark et al., 2008). Based on that, the forest fires have caused the huge lost of carbon stock potential. The lost could be avoided by maintaining the peat swamp forest from fires.

Conclussion

Forest fires caused the changes in the natural regeneration including composition, structure, species and changes in potential carbon stock of the peat land's surface. Fire management and prevention will ensure the regeneration of degraded peat swamp forest.

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References

Atmoko T, Arifin Z, and Priyono. 2011. Structure and Distribution of Dipterocarpaceae Trees in Merapit Seed Stand, Central Kalimantan. Jurnal Penelitian Hutan dan Konservasi Alam 8 (3) : 399 - 413.

Bismark M, Subiandono E, and Heriyanto N.M. 2008. Diversity, Potential Species and Carbon Content of Mangrove Forest at Subelen River, Siberut, West Sumatra. Jurnal Penelitian Hutan dan Konservasi Alam 5 (3) : 297 - 306.

Evans, J. 1982. Plantation Forestry in The Tropics. Clarendon Press. Oxford.

Heriyanto N.M. and Subiandono E. 2012. Composition and Structure, Biomass, and Potential of Carbon Content In Mangrove Forest At National Park Alas Purwo. Jurnal Penelitian Hutan dan Konservasi Alam 9 (1) : 023 - 032.

Kuijk, M. 2008. Forest Regeneration and Restoration in Vietnam. PhD thesis Utrecht University. Wohrmann Print Service, Zupthen.

Qirom M.A; Saleh M.B. and Kuncahyo. 2012. Application of alos palsar image for estimation of carbon stock in acacia forest. Jurnal Penelitian Hutan Tanaman 9 (3): 121 – 134.

Samsoedin I and Heriyanto N.M. 2010. Structure and Species Composition of Lowland Disturbed Forest at Lepan River Forest Complex, Sei Serdang, Gunung Leuser National Park, North Sumatra. Jurnal Penelitian Hutan dan Konservasi Alam 7 (3) : 299 - 314.

Samsoedin I., Dharmawan I. W. S. and Siregar C. A. 2009. Carbon Biomass Potency of Old Growth Forest and Thirty Year-Old Logged Over Forest in Malinau Research Forest, East Kalimantan. Jurnal Penelitian Hutan dan Konservasi Alam 6 (1) : 047 - 056.

Siarudin M. and Rachman E. 2008. Biomass Production and Litter Fall on Blanakan Mangrove Area, Subang, West Java. Jurnal Penelitian Hutan dan Konservasi Alam 5 (4) : 329 - 335.

Sidiyasa K. 2012. Characteristic of Peat Swamp Forest in Tuanan and Katunjung, Central Kalimantan. Jurnal Penelitian Hutan dan Konservasi Alam 9 (2) : 125-137.

Siregar C.A and Dharmawan I.W.S. 2011. Carbon Stock of Dipterocarp Natural Forest Stands at PT. Sarpatim, Central Kalimantan. Jurnal Penelitian Hutan dan Konservasi Alam 8 (4) : 337 - 348.

Siregar C.A and Heriyanto N. M. 2010. Accumulation of Carbon Biomass Under Secondary Forest Scenario in Maribaya, Bogor, West Java. Jurnal Penelitian Hutan dan Konservasi Alam 7 (3) : 215 - 226.

The development analysis of jelutong-based agroforestry system for rehabilitation of degraded peatland at Central Kalimantan Province

Marinus Kristiadi Harun and Tri Wira Yuwati
Banjarbaru Forestry Research Institute, Jl. Ahmad Yani Km. 28,7 Landasan Ulin, Banjarbaru, South Kalimantan. Phone number: 08164565497.

E-mail: marinuskh@yahoo.co.id

The aim of this research was to analyze the development of jelutung in the agroforestry system for the rehabilitation of the degraded peatland fulfilling technically applicable and environmentally friendly. Primary data of this research were collected via interviews, observations, field visits and focus group discussion (FGD) involving all parties. The research results showed that the development of jelutung in agroforestry system was technically applicable, and environmentally friendly for the rehabilitation of peatland degradation. There were 5 certified jelutung seed sources in Central Kalimantan Province that can produce about 126,920,000 seeds per years. The local people's nursery can produce 1 – 3 million readily planted jelutung seedlings per years. In thin peatland there were 3 agroforestry systems that have already been developed by the local people. In thick peatland, there were 2 agroforestry systems that have already been developed by the local people. Jelutung growth performances on a variety of agroforestry systems showed that the annual stem height increment reached 86.55 – 127.94 cm and stem diameter increased 1.56 – 2.15 cm. On the environmental aspect,the diversity of peatland macro-fauna covered with jelutung agroforestry was greater than that covered with monoculture and abandoned land with Shannon Wiener index values of 1.8; 1.2; 1.69 respectively for PSM method.

Keywords: jelutung, agroforestry system, rehabilitation, peatland.

Introduction

The condition of peatland in Central Kalimantan Province requires rehabilitation in order to prevent further damage. One of the systems that can be used for this purpose is agroforestry-based system with local species. Agroforestry is a collective term for land use systems and technology, which is implemented in a planned manner with a land unit combines woody plants (trees, shrubs, palms, bamboo, etc.) with agricultural crops and/or animals (livestock) and/or fish, performed at the same time or take turns forming ecological and economic interactions between the various components (Lundgren and Raintree, 1982).

Implementation of agroforestry systems to rehabilitate degraded peatlands requires the selection of the right kind of technical, social, economic and environmental. Jelutung is one of the indigenous tree species with high economic value. The wood has excellent properties for pencil slate industry and gum industry (Daryono, 2000). The development of jelutung (Dyera polyphylla) with agroforestry systems are expected to realize the sustainability of the production function and the environmental protection function of peatlands.

The aims of this paper is to analyze the technical feasibility, social, economic and environmental development jelutung with agroforestry systems to restore degraded peat land in Central Kalimantan Province.

I .MATERIALS AND METHODS

1.1. Time and Place

The research was conducted for 6 months from February to July 2011, which is located in the five villages, namely: Jabiren, Mentaren II, Tumbang Nusa, Kalampangan and Kereng Bangkirai, Central Kalimantan Province.

1.2. Materials and Equipments

Materials: soil samples, plastic bags, plastic buckets (size 15.5 x 12 x 11 cm), the chemicals in the laboratory analysis, a list of questions (questionnaire), the tally sheet. Equipments: tape measure, phiban, measuring poles, GPS, drill peat, digital cameras, stationery, tape recorders, calculators and computers.

1.3. Methods

The data collected in this study includes qualitative and quantitative data. The data based on its source, can be divided into primary and secondary data, which is divided into two (2) aspects, namely the technical aspects and environmental aspects. Primary data obtained through interviews with informants, in-depth interviews with key informants, observations and direct measurements in the field and Focus Group Discussion (FGD) with stakeholders.

II. RESULTS AND DISCUSSION

2.1. Technical feasibility

There are 5 certified jelutung seed sources in Central Kalimantan Province that can produce about 126,920,000 seeds per years. The local people's nursery can produce 1 – 3 million readily planted jelutung seedlings per years. Agroforestry system that have been developed by local farmers in peat land has specific characteristics. It is can be used as a basic for further improvements. Some important aspects of the cultivation of the jelutung based agroforestry systems that are typical in thin peat (Jabiren and Mentaren II) and thick peat (Tumbang Nusa and Kalampangan) as described below.

The important aspect of consideration of jelutung cultivation with agroforestry systems in shallow peat (peat thickness of 50-100 cm) were: land preparation, soil fertility management, water management and cropping patterns. First, land preparation. Land preparation techniques performed by local farmers can be divided into two, namely: mounds and surjan (sunken bed). The application of agroforestry systems in thin peat ideally is using surjan system. It is one way to overcome the influence of flood so that the rice can be planted in addition to other types of plants that can not stand innundation for the optimization of land. The surjan technique enables the application of various cropping pattern and diversification of commodities. At surjan engineering, land is divided into 80% sunken beds, which is part of the lower land and 20% of the mounds (raised beds), which is part of the higher land. Sunken beds usually for growing rice or other crops that resistant to innundation, while the mounds planted with rubber, jelutung, crops, fruit trees or forage and fodder. Second, the management of soil fertility. Source of nutrients for the plants obtained by processing straw yields of rice and weeds by rolling and spreading techniques. This technique was the local knowledge of local farmers in obtaining sources of nutrients for crop cultivation. This was done by rolling the straw and weeding at one of the stages of activities to prepare the land in rice cultivation.

The process of making organic fertilizer were as follows: (a) cleaning/weeding using a trowel, (b) fresh-cut weeds were left for 2-3 days for withering process, (c) the wilted weeds were rolled (d) the weathered weerds were then spread evenly. Another form of local wisdom in managing soil fertility was three times transplantation (taradak, lacak and ampak) in addition to anticipating labor shortages as well as to maintain soil fertility. Practicing "rolling and spreading" was combined with other techniques such as land preparation, water collection system (dignity) and the manufacture of glaze (bund). Wisdom of farmers in utilizing waste crops and weeds as organic material is specific to each individual farmer. Third, the management of water. This activity was carried out by local farmers include the manufacture of drainage channels and "tabat" systems. The "tabat" system done to maintain water levels during the growing season in March-April. The "tabat" opened at the end of the dry season or the rainy season to remove poison elements (Al, Fe, H2S). Fourth, cropping pattern. Agroforestry systems based on jelutung species that have been developed by local farmers can serve as the basis for further development. Cropping patterns that have been developed by local farmers can be grouped into three patterns, namely: (a) agrosilvofishery, (b) mixed cropping, and (c) alleycropping. Figure 6 decribe those models.

Important aspects of jelutung cultivation with agroforestry systems on deep peat (peat thickness of 200-300 cm) includes land preparation, planting, soil fertility management, water management and cropping patterns. First, land preparation. Land preparation is the most important aspect in the cultivation of agroforestry systems in the thick peat. Land preparation is done by dividing the plot of land in the trenches as a barrier between the plots. The drainage channel have double function, they are as the water system management and as firebreaks, especially for the underground fire. The existence of the trench can maintain ground water (soil moisture) between 60-100 cm from the surface of the soil for better soil aeration and drainage. Trench sizes that were used for 1 ha land area is 50-100 cm for the width and depth of the trench. Compaction techniques could be grouped into two techniques: using vegetation and compaction is done in the planting hole. Vegetation commonly used for soil compaction is a pineapple and cassava. Cassava plants that have resistance to high acidity and can serve to accelerate the ripening process of peat (Muslihat, 2003). Second, planting. Two things to note in jelutung planting in peatlands are a condition of making the planting hole and seeds ready for planting. Planting and hole making techniques commonly done by practitioners in the field can be explained as follows: (1) the location of the planting hole was cleared by weeding (2) at the point of decision-root planting is done to allow the seedling fern direct contact with a layer of peat and enumerating peat to be compact (dense) so that no air cavity, (3) make the planting hole size with polybag to be planted, (4) ripped just below the surface of the polybag without releasing the seeds. This is necessary so that when there are fluctuations in soil moisture seed media is not broken because it has not fused with peat in the field, (5) poly bag insert into the planting hole that was made by the polybag end position parallel to the ground surface and the bottom of the peat layer not touching polybag roots fern, (6) poly bag compresses around the peat that has been planted in order to blend with the soil in the field. Third, the management of soil fertility. Giving ameliorant material is very important to improve the condition of the land. Ameliorant materials commonly used by local farmers is lime, mineral soil and ash from burning grass and litter. Fourth, the water management. The setting is done by making the soil moisture drainage ditch that surrounds the land. Size of the drainage ditch outside (circumference) of land is 50-100 cm in width and depth, while in the trenches measuring 30-50 cm in width and depth. In addition to drainage ditches, farmers also make 1m2 sized wells with a depth of 2 m as a source of water for watering crops. For farmers with more capital, in addition to the wells they have also made boreholes as a source of water in anticipation of the dry season. Fifth, cropping pattern. Agroforestry systems that have been developed by local farmers in the thick peat can be used as a basis for further development. Development of jelutung with agroforestry systems to restore degraded peat land in Central Kalimantan province, prioritized on peatlands have been converted but less suitable for agriculture and plantation crops. Development jelutung swamp with agroforestry system must go through a diagnostic activity to look at community needs and designing through active participation in order to be practiced by the local farmers.

2.1.1. The Growth Performance of Jelutung

Table 1 presents data on average stem diameter, plant height, stem diameter growth increment and height increment jelutung at various typologies and cropping patterns.

Table 1: The performance of jelutung growth on various typologies of peatland and agroforestry systems in Central Kalimantan Province

Location, Peatland Typology and Planting Pattern	Age (Year)	The performance of jelutung growth (cm)			
		Mean of diameter	DB/year	Mean of Height	Height /year
Kalampangan, thick Peatland, *alleycropping* system I	6,00	10,39	1,73	617,13	102,86
Kalampangan, thick Peatland, *alleycropping* system II	5,25	8,69	1,66	454,38	86,55
Tumbang Nusa, thick Peatland, *mixcropping*	5,30	10,11	1,96	626,70	116,03
Jabiren, thin peatland, *mixcropping* used surjan technique	5,25	10,11	1,92	671,70	127,94
Mentaren II, sulfid acid thick Peatland, *agrosilvofishery* used surjan technique	6,50	11,03	1,60	800,60	120,00
Mentaren II, sulfid acid thick Peatland, *alleycropping* used surjan technique	6,50	13,98	2,15	716,18	110,18
Mentaren II, sulfid acid thick Peatland, *mixcropping* used surjan technique	6,50	10,15	1,56	581,58	89,47
Mean	**5,9**	**10,64**	**1,80**	**638,32**	**107,58**

The data in Table 1 shows that the high increment of jelutung with agroforestry systems on various typologies of peatlands is 86.55 to 127.94 cm per year, while the diameter increment was 1.56 to 2.15 cm per year. This compared with growth in its natural state jelutung on the island of Sumatra, diameter increment of jelutung ranged from 1.5 to 2.0 cm / year (Bastoni and Riyanto, 1999). While on jelutung swamp cultivated in semi-intensive maintenance of Sumatra island diameter increment can be obtained from 2.0 to 2.5 cm / year (Bastoni, 2001). Jelutung growth measurement results conducted by Balittaman Palembang in 2001 shows at the age of 9 years, height increment ranges from 164-175 cm / year, and the diameter increment ranged from 2.18 to 2.38 cm / year (Bastoni, 2001). Results jelutung growth increment on the island of Sumatra which was higher than the growth of cultivated jelutung with agroforestry systems in this study due to the more fertile peat. Indrayatie and Suyanto (2009) showed that from the topographical aspect, jelutung prefered land form plains, meaning that areas with shallow ground water, either permanently or seasonally flooded, lowland elevation (<100 m asl.), living in a place open without shade or associated with other vegetation. On edaphic aspects, jelutung can live on mineral soils (alluvial) and organic soil. These conditions were presented to area alluvial subsystem - such as marine wetlands (swamp), tidal marsh (marsh), deltas, tidal flats; regional sub-systems such as alluvial floodplain (flood plain), the path meanders (meanders belt); area alluvio - colluvial sub-systems such as isolated basin area (isolated miniplain); area closed alluvial sub-systems such as wetlands without the influence of sea water (swamp or marsh without marine influence). The above description explains that the development of agroforestry systems to jelutung to restore degraded peatlands of technical feasibility parameters is feasible.

2.2. Environmental feasibility

2.2.1. Soil Fertility

Table 6 explains that for the parameters pH, Al dd, H dd, Al saturation, saturation of H at thented with jelutung agroforestry patterns was higher than the peat soils planted with monoculture crops. Na dd, dd Mg, CEC, H dd, saturation of H, K and SO4 total at the land jelutung agroforestry pattern higher than the abandoned peatlands. Cation exchange capacity (CEC) is very high (90-200 me/100 g) in all peatland typologies in this study with a base saturation (KB) can lead to very low availability of nutrients, especially K, Ca, and Mg. Moreover, saturation of bases (KB) is very low in all peatland typologies which must be increased in order to achieve 25-30% of bases can be utilized plants are swapped (Hardjowigeno, 1996). C / N peat are high (> 30) causes less nutrient nitrogen available to plants even though the total N analysis showed a higher rate. P elements in peat soils found in the form of organic P and less available to plants. P fertilization with quickly available fertilizer will cause easily leached phosphate ions and reduces the availability of P to plants. The addition of iron can reduce P leaching (Soewono, 1997). P leaching can be reduced by adding iron-rich mineral soil and Al (Salampak, 1999).

Table 2: Data analysis laboratory chemical properties of peat

Parameter	Location			
	Kalampangan		Tumbang Nusa	
	Agroforestry	Monoculture Agriculture	Agroforestry	Non Productive Land
pH	3,94	3,93	3,67	4,00
N Total (%)	0,40	0,45	0,37	0,43
C Organik (%)	48,58	51,78	55,12	54,76
Nisbah C/N	121,45	115,07	148,97	127,35
K dd (me/100g)	0,076	0,15	0,09	0,12
Na dd (me/100g)	0,014	0,06	0,04	0,03
Ca dd (me/100g)	2,34	4,13	1,28	2,47
Mg dd (me/100g)	1,76	2,58	0,90	0,88
KTK (me/100g)	147,50	361,17	137,50	90,83
Al dd (me/100g)	2,40	2,30	0	0
H dd (me/100g)	5,27	3,03	2,83	2,00
KB (%)	2,86	3,76	1,80	4,24
Saturation of Al (%)	20,80	19,73	0	0
Saturation of H (%)	48,94	26,66	55,29	37,18
P total (mg/100 gr P_2O_5)	4,21	24,50	7,82	12,71
K total (mg/100 gr P_2O_5)	4,32	18,33	6,94	5,51
P Bray 1 (ppm)	12,55	12,59	19,36	29,82
SO_4 (ppm)	102,12	119,20	112,66	101,69

III. CONCLUSIONS

It can be concluded that:

a. The development of jelutung with agroforestry systems to restore degraded peatlands in terms of technical aspects worth doing; with the ability to supply certified seeds indicator as 126.92 million seeds per year, the ability to supply seedlings ready for planting 1-3 million stems per year; there are patterns of agroforestry based jelutung types that have been developed by local farmers in several typologies of peat swamp jelutung growth and performance for high increment ranged from 86.55 to 127.94 cm per year, for diameter increment ranged from 1.56 to 2.15 cm per year.

b. The development jelutung with agroforestry systems to restore degraded peatlands in terms of environmental aspects worth doing, showing that agroforestry jelutong has chemical properties and microclimate better than monoculture.

IV. ACKNOWLEDGEMENT

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V. REFERENCES

Bastoni. 2001. Pertumbuhan hasil dan kualitas tapak hutan tanaman di Sumatera bagian Selatan. Laporan Hasil Penelitian. Balai Teknologi Reboisasi Palembang. Tidak dipublikasikan.

Bastoni dan A.H. Lukman. 2006. Prospek pengembangan hutan tanaman jelutung (Dyera lowii) pada lahan rawa Sumatera. Di dalam S. Hidayat, H. Daryono, H. Suhaendi, M. Turjaman dan H. Mardiah [Editor]. Optimalisasi Peran Iptek dalam Mendukung Peningkatan Produktivitas Hutan dan Lahan. Prosiding Seminar Hasil-hasil Penelitian. Jambi, 22 Desember 2005. Pusat Penelitian dan Pengembangan Hutan dan Konservasi Alam. Bogor. pp 19 – 30.

Bastoni dan H.D. Riyanto. 1999. Teknik Silvikultur untuk Rehabilitasi Hutan dan Lahan Basah Bekas Tebangan di Sumatera Selatan dan Jambi. Laporan Hasil Penelitian. Balai Teknologi Reboisasi Palembang. Tidak dipublikasikan.

Budiningsih, K. dan Ardhana, A. 2011. Laporan Hasil Penelitian Tahun Anggaran 2010. RPI Pengelolaan Hutan Tanaman Penghasil Kayu Pertukangan. Analisis ekonomi dan kelayakan finansial pembangunan hutan tanaman penghasil kayu pertukangan. Banjarbaru. Januari 2011. 44 halaman.

[Dephut] Departemen Kehutanan. 2009a. Peraturan Menteri Kehutanan Nomor P.19/Menhut-II/2009 tentang Strategi Pengembangan Hasil Hutan Bukan Kayu Nasional. Departemen Kehutanan. Jakarta.

[Dephut] Departemen Kehutanan. 2009b. Peraturan Menteri Kehutanan Nomor P.21/Menhut-II/2009 tentang Kriteria Dan Indikator Penetapan Jenis Hasil Hutan Bukan Kayu Unggulan. Departemen Kehutanan. Jakarta.

Daryono, H. 2000. Teknik Membangun Hutan Tanaman Industri Jenis Jelutung (Dyera spp.). Informasi Teknis Galam No. 3/98. Balai Teknologi Reboisasi Banjarbaru. Kalimantan Selatan.

Indrayatie, E.R. dan Suyanto. 2009. Penyusunan Database Digital Karakteristik Habitat Jelutung (Dyera polyphylla Miq. V. Steenis) di Lahan Basah Kalimantan Selatan. Laporan Penelitian. Fakultas Kehutanan. Manajemen Hutan. Universitas Lambung Mangkurat (tidak dipublikasikan).

Karyono, O.K. 2008. Peluang Usaha Budidaya Jelutung (Dyera costulata) pada Lahan Gambut di Kalimantan Tengah. Majalah Kehutanan Indonesia (MKI) Edisi II/2008. Jakarta.

Muslihat, L. 2003. Teknik Penyiapan Lahan untuk Budidaya Pertanian di lahan Gambut dengan Sistem Surjan. Wetlands Internasional Indonesia. Indonesia Programme. Bogor.

Noor, M. 2001. Pertanian Lahan Gambut: Potensi dan Kendala. Penerbit Kanisius. Yogyakarta.

Rusmana, E. 2007. Teknik Produksi Bibit Jenis-Jenis Pohon Rawa Gambut Secara Generatif Dan Vegetatif. Bahan Ajar disampaikan pada Alih Teknologi Pembangunan Hutan Rakyat Sistem Agroforestri. Banjarbaru. 15 halaman.

Rusmana, E., P.B. Santoso dan B. Hermawan. 2005. Teknik Pembuatan Bibit Stek dengan Metode KOFFCO. Balai Penelitian Kehuatanan Banjarbaru. Banjarbaru. 15 halaman.

Santosa, P.B. 2008. Teknik Penanaman di Lahan Rawa Gambut. Bahan Ajar disampaikan pada Alih Teknologi Pembangunan Hutan Tanaman. Balai Penelitian Kehutanan Banjarbaru. Banjarbaru. 18 halaman.

Formation of peat forests and life of inhabitants

Harukuni Tachibana
Research institute of water environmental science research,
Kankyou Create Co. Ltd

Introduction

Tropical rain forests are not only lumber producing area, but also vast warming controlling area. The area absorbs carbon dioxide increasing in the world. The forests save the earth from environmental destruction. The author has been studying water environment of peat forests of Palangkaraya, Central Kalimantang, Indonesia since 2006. This time, I define water environment of peat forests and condition of peat forest formation from water analysis data of River Sebangau which runs through a peat forest, west of Palangkaraya , and ground water and rivers flowing out of peat areas of Kalanpangan in the south of Palangkaraya. In addition, I thought about recovery of the peat forests destroyed by cutting and fire from the data of water quality.

Method

The objects of the study are rivers running from the vast northern peat forests (upper and downstream of R. Sebangau), ground water of peat forests where trees were cut down in the south of Kalanpangan peat forest and draining canals from peat area, and deep ground water of Palangkaraya. A big river, Kahayang River, which runs through western area of Palangkaraya, is made another object to compare with rivers which run out from peat area.

In this report, KIYA point of R. Sebangau is the model point to know the typical water of rivers which run out from natural peat forests. At KIYA point, the model of water quality pattern of rivers of natural peat forests was researched mainly by sampling at regular intervals. And from the data of ground water of Kalanpangan peat forest and draining canals, we know the typical water quality of peat forests whose trees were cut down or destroyed by fire.

From the information, movement of flow and components of water were explained. Formation process of peat forests was studied relating to deep ground water quality under peat forests. And the way of management to preserve peat forest was studied.

Results and Discussion

1. Water quality of rivers flowing out of peat forests (An analysis of water quality of R. Sebangau.)
Much water flows into upper reaches of R.Sebangau from natural tropical peat forest. The character of water quality at KIYA point is written in Tachibana 2006. Though woods are still cut in upper stream region, its influence on river water quality is not so much as in downstream region. The upper reach is a river of natural peat forest. Seeing from an airplane, the upper stream region looks like a vast natural forest. The average water quality and coefficient of variation CC are shown in Table 1. Water quality does not change while there is much river water flow change as shown in Figure1. Concentration of soluble organic carbon is high and coefficient of variation is small. Concentration of inorganic components is low (the composition is similar to rain) and electric conductivity is high. The high electric conductivity is regarded by influence of

organic carbon. In addition, a high correlation was seen between electric conductivity (EC) and concentration of organic carbon (DOC) as shown in Figure 2. The rain contains organic substance in a short time. In tropical peat forest, organic carbon elutes to a water system as a result of rapid biodegradation of the tree peat.

Table 1 Average water quality and C.V. n=8 C.V. : Coefficient of variation

	Average	C.V.
	mg/l	mg/l
Q	19.25	0.49
pH	3.84	0.03
EC	52.66	0.04
TOC	39.82	0.09
DOC	37.56	0.10
POC	2.26	0.36
TN	0.77	0.14
DN	0.76	0.15
PN	0.01	1.11
NO3−−N	0.01	1.09
NH4+−N	0.06	0.44
TP	0.01	0.30
DP	0.00	0.35
DRP	0.00	0.13
Na+	0.79	0.38
Cl−	0.71	0.23
SiO2	15.23	0.06
TN/TP	145.86	0.37
TIN/DN	0.09	0.44

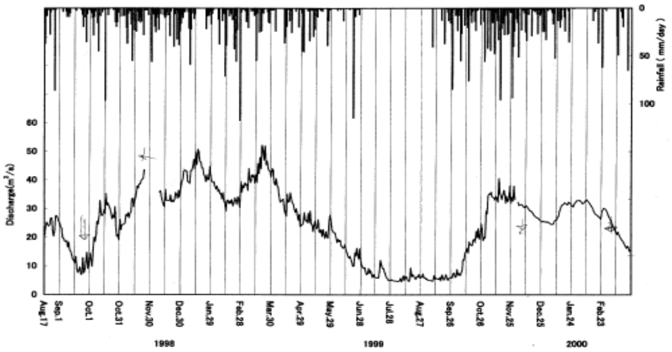


Figure 1 Rainfall and flux at KIYA point

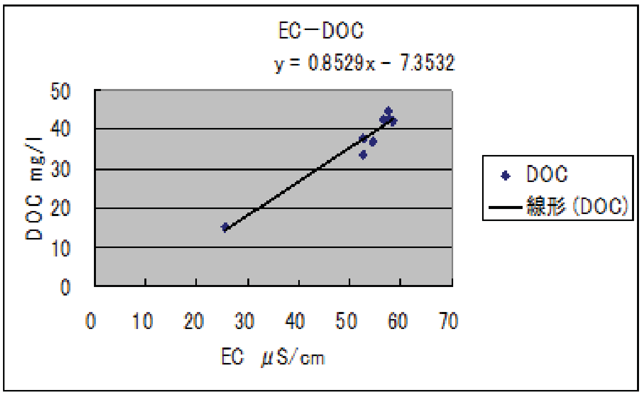


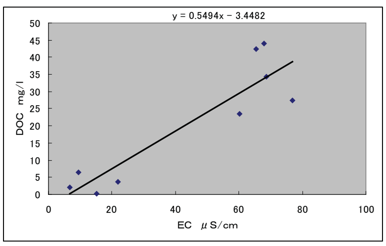
Figure 2 Relationship between EC and Organic Carbon

2. Analysis of ground water of peat forests of Kalanpangan

Ground water quality was studied at wood-cut area and burnt area of peat forests. The research points are around a drainage canal near Prof. Suwido's office in the north of peat area. In this area, only a few meter high young trees grow. The results analyzed at the researching point are shown in Table 2. The data that show relationship between EC and concentration of DOC analyzed at the experimental room in Japan are shown in Figure 3. Electric Conductivity (EC) does not rise under 2 meter deeper part. Woods of peat forests are soon dead after cut down. The tree peat is decomposed in a short time after death of trees. The ground water under 2– 4m from the surface moves at considerably high speed without organic decomposition. Suzuki 1997 supposes that peat forest is a floating island. So it is thought that ground water mixed with rain water moves through the bottom layer like a river.

Table 2 pH and EC

2011.3			2012.3		
Depth m	pH	EC μS/cm	Depth m	pH	EC μS/cm
0	3.85	47.3	0	4.26	33.2
			0.5	4.08	43.6
1	3.08	538	1	3.97	59.1
2	3.27	379	2	3.97	60.7
			2.1	4.01	67.3
3.9	3.6	84.4			



Figur 3 Relationship between EC and DOC (Suwido office St. Data of lab.)

3. Water quality of drainage canal from Kalanpangan peat area

Drainage canals that run in the north Kalanpangan peat area flow into R. Sebangau and R. Kahayang that run both sides of the peat area. The canals were used to carry woods and to drain ground water of the area to make agricultural land.

It is a big problem what to do with the canals to recover the original state of the area. Canals are now the people's traffic ways and fishing sites. It is thought to dam the canals, but it is not certain if it will make trees grow thick as before.

Water quality of a canal (St.4) is nearly equal to 2~3m deep water quality of the peat area. (Table 3) The canal water quality is different from both big rivers. Canal water is influenced by rain water every time. Damming gathers rain water, but dose not gather nutrients. Big trees do not grow by this water.

Table 3 Water qulity of representative points

		pH	EC	DOC	DTN	DTP
			μS/cm	mg/l	mg/l	mg/l
2010.3	Canao(Dam4)	3.7	95.4	23.8	3.55	0.058
	Deep Ground Water	4.9	9.5	6.5	0.51	0.005
	R. Sebavgau	3.8	60.3	23.4	0. 85	0. 013
	R. Kahayang	5. 8	13. 1	15. 5	0. 52	0. 022
2011.3	Suwido St. 3.9m	3.38	84.4	26.0	0.51	0.190

4. Water quality of peat land and formation of forests.

From a macro point of view, concentration of inorganic components of groundwater of peat forests is low similar to rain water, and change of concentration is very small by observation of water quality at KIYA point of R. Sebangau.

Water movement is different by seasons (in this area, dry and rainy), and staying time in peat layer is thought quite different in both seasons. It means that decomposition rate of organic matter in the surface layer is high. Ground water quality (under 2~3m) and canal water quality are similar to each other. Therefore trees need long roots to reach deep basic layer to get nutrients.

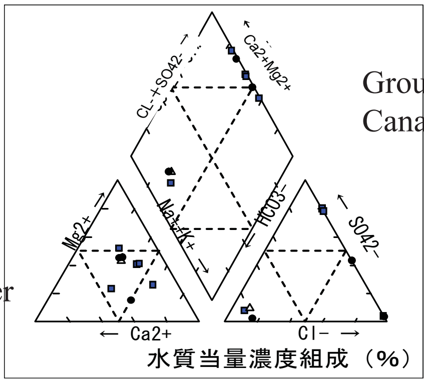


Figure 4 Trilinear Diaguram of representative points

5. Reforestation and forest conservation

Reforestation and conservation of forest destroyed by felling and fire were considered. Decades ago, this area has been thickly covered with big trees, Alan (Dipterocarpaceae) being the major one. Sinker root of Alan grows several meters to reach the sand layer containing many nutrients in its ground water. Industrial tree felling and fire destruction of forest interrupt supplying nutrients from sinker roots. Therefore, it is difficult for big trees to grow.

In the present condition, we have to know the basic forest formation system. The inhabitants need to live caring about natural characters of the forest until they find a system to bring up big trees. . Prof. Suwido insists on 4 lifestyles.

1. Cultivation of the gum trees. 2. Use of the rattan. 3. Cultivation of rice. 4. Cultivation of fish in the fire prevention pond. Inhabitants had better care about the forests.

Refernces

Harukuni Tachibana, Rofiq Iqbal, Saori Akimoto, Mutsuko Kobayashi, Shunji Kanie, Akio Mori, Tadaoki Itakura, Hidenori, Takahashi, Kohken Utosawa, Nyoman Sumawijaya, Salampak Dohong, Untung Darung, Suwido Limin, Chemical Characteristics of water at the upper reaches of the Sebangau River Central Kalimantan, Indonesia, Tropics,Vol.15. no.4, 411-416, 2006.

Kunio Suzuki, The floating forest 水に浮かぶ森 japanese Shinzansya,1997

Methanotrophic activity in tropical peatland as affected by drainage and forest fire

Hironori Arai[1)], Abdul Hadi[2)], Untung Darung[3)], Suwido H Limin[3)], Ryusuke Hatano[4)], and Kazuyuki Inubushi[1)*]

[1)] Graduate School of Horticulture, Chiba University, Matsudo, Chiba 271-8510, Japan
[2)] Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru 70714, Indonesia
[3)] Faculty of Agriculture, University of Palangka Raya, Palangka Raya 73112, Indonesia
[4)] Graduate School of Agriculture, Hokkaido University, Sapporo, 060-8589, Japan

[*] E-mail address: inubushi@faculty.chiba-u.jp

Flux of methane, one of greenhouse gases, from soil is the balance between methane production and methane oxidation in soil, carried by unique microorganisms, anaerobic methanogens and aerobic methanotrophs, respectively. Effect of drainage and forest fire on methanotrophic activity of forest soils in the tropical peat soils was studied by analyzing methane fluxes, population of methanotrophs, and the incubation experiment to compare methane production and oxidation activities with respect to effects of flooding and litter fall. Small amount of methane fluxes were observed from the soils in drained forest, natural forest and burnt forest with no significant differences among the sites (-0.02±0.01 to 0.36±0.30 mg C m−2 hr−1). Water filled pore space (WFPS) showed a positive relationship with methane fluxes and a negative relationship with populations of methanotrophs, each significantly. Incubation experiment showed stronger methane oxidation activity than methane production activities without litter application even under flooded condition. These results indicated that the recalcitrant soil organic matter would probably not act as substrate of CH4 or reinforce of CH4 oxidation. Under the environment, the methanotrophic activity is controlled by WFPS by adjusting oxygen supply into the peat soils.

Keywords: gas flux, methane, peatland.

Introduction

Because of high organic carbon and hydrological condition, tropical peat soils can become source of greenhouse gas emissions (Inubushi et al., 2003). Peat swamp forests have been logged intensively through the official concession system as well as the other forest on mineral soils (Wösten et al., 2008). The canals that are dug into the surface of the peat soils enhance drainage to decline the groundwater level and expose the peat soils to the risk of fire and microbial decomposition. In addition, large part of tropical peatlands in Southeast Asia have been converted to agriculture since the 1970s to accelerate microbial decomposition which results in significant carbon outputs to the atmosphere contributing to climate change processes (Hirano et al., 2007; Takakai et al., 2006; Toma et al., 2011).

Drainage of peat soils results in carbon dioxide (CO2) and nitrous oxide (N2O) emissions of globally 2 to 3 Gt CO2-eq per year (Joosten & Couwenberg, 2009). Although rewetting of peatlands suppresses aerobic CO2 and N2O emissions but also leads to increased methane (CH4) emissions. To address such a concern, not only CH_4 producing processes but also methane consuming processes requires to be assessed.

Since few study has been conducted to research effect of drainage and forest fire on methanotrophic activity in peat soils, this study was conducted with in situ CH_4 fluxes measurements, the enumeration of methanotrophs, and the incubation experiment with respect to effects of flooding and litter fall on CH_4 production and oxidation activity.

Methods

Field observation was conducted in Kalampangan village near Palangka Raya (2^{o}S, 114^{o}E) in Central Kalimantan, Indonesia from July and September 2010. Our research sites are distributed to 5 sites. a tract of not drained natural forest (UNF: 2^{o}19'S, 113^{o}54'E), a tract in drained forest (DF: 2^{o}21'S, 114^{o}02'E), 3 tracts of burned forest (BF: 2^{o}19'S, 114^{o}01'E) as described in Takakai et al. (2006) and Hirano et al. (2007). Undisturbed 100 cm^3 core samples and composite soil samples collected from the depth of 0 to 10 cm. Undisturbed soil cores were sampled for measurement of soil volume proportion by three phase meter. The core samples were weighed, before put on the oven dried at 105^{o}C for 48 h, and after dried, the samples were reweighed to calculate soil moisture contents, bulk density, and water filled pore space (WFPS). Based on bulk density, chemical and biological data ware converted to area base data. The other soil physicochemical properties are measured using methods described in Inubushi et al. (2003). For enumeration of methanotrophs in soils, undisturbed soil core samples were dispersed for 1 min with 100 mM sodium phosphate buffer (pH 7.0) and coarse particles were allowed to settle for 1 min. Soil suspensions were then serially diluted and applied to the MPN method with 48-well microtiter plates as described in Saitoh et al. (2002). Gaseous fluxes were measured accompanied with soil samplings. Gas samples were taken by closed cylindrical PVC chambers (Furukawa et al., 2005; Hadi et al., 2005). The gas samples were taken from the triplicate chambers at 0, 10, 20 minutes using 30 ml syringes and then immediately transferred to 22 ml evacuated glass vials with butyl rubber stoppers. The concentrations of CH_4 were quantified using a gas chromatograph equipped with a flame ionization detector. With respect to the water level and litter fall which would be differed with land-use changes, incubation experiment with the peat soils was conducted. Five g of peat soils (WFPS 58%) were taken in DF, September 2010. These soils were applied to 30ml test tubes with 5 replication and 4 treatments as control treatment: no amendment, litter treatment: 0.5g of litter was applied on soils in each tube, which was obtained from soil surface and passed through a 5mm mesh sieve, flooded treatment: flooded with 10ml of distilled water, flooded and litter treatment: applied with 0.5g of litter and flooded as former treatments. CH_4 concentration in head space was measured with the above-mentioned gas chromatography before and after weekly head space air ventilation. All statistical analyses were carried out using SPSS 11.0 software for Windows. Means and standard deviations of the data were calculated. Mean comparison was done using the Tukey-Kramer's multiple comparison procedure with a SPSS 11.0 software.

Results

As physicochemical characteristics of the peat soils, high porosity and carbon content were measured in all peat soils but not varied apparently as affected by land-use difference (porosity: 88.7 to 91.8 %, carbon content: 494 to 568 mg kg^{-1}). However, WFPS of peat soils varied with land use difference (53.7 to 97.3%) and peat soils in DF showed lower WFPS than in the other soils. Small amount of CH_4 fluxes were observed from the soils in drained forest, natural forest and burnt forest (-0.02±0.01 to 0.36±0.30 mg C m^{-2} hr^{-1}). Negative CH_4 fluxes were measured in DF where WFPS of soils are lower than other peat soils. WFPS showed a positive relationship with methane fluxes (r=0.75, n=10, p<0.05), and a negative relationship with populations of methanotrophs (r=-0.79, n=10, p<0.01), both significantly.

Incubation experiment showed significant decreases of CH4 concentration in control treatments, litter application treatments and flooding treatments (Fig. 1). Decrease of CH4 concentration in flooding treatments were significantly smaller than in control treatments. CH4 concentration in litter application treatments decreased significantly more than in the other treatments. Increase of CH4 concentration in head space was measured only in litter application – flooding treatments.

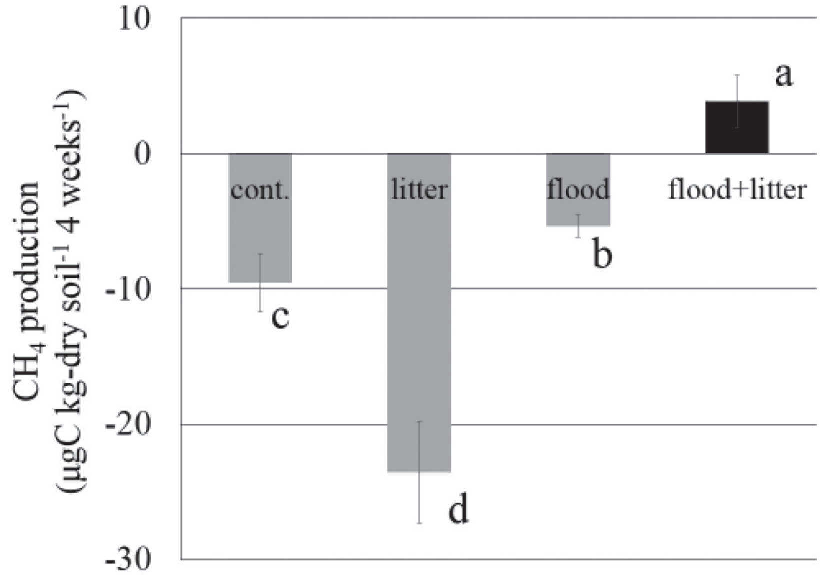


Figure 1. CH4 production as affected by addition of litter and water condition.
Error bars show standard deviations (n=5). Cumulative CH4 changes for four weeks are significantly different when they are marked with the different letters, based on Tukey-Kramer HSD test (p<0.05).

Discussion

Consisting of high total carbon content (494 to 568 mg kg-1), all of the peat soils studied in this study showed high porosity (88.7 to 91.8 %) and indicated that its high air permeability allow the oxygen to be supplied into the soil immediately following soil moisture decrease. Even from the peat soils, WFPS of which is higher than 90%, small CH4 emissions were measured (-0.02±0.01 to 0.36±0.30 mg C m−2 hr−1) and these values are small as reports in Inubushi et al. (1998) as 1.1±0.61 to 1.39±0.82 mg CH4 m−2 hr−1 in sago palm plantation and Melling. et al. (2005) as -4.53 to 8.40 µg C m−2 hr−1 in forest. From the viewpoint of substrates of CH4, Segers (1998) revealed that most methane in peat columns is derived from recently fixed (young) carbon. Besides, methane production decreases when labile substrates are depleted, for example with depth below the water table and the production also can be stimulated substantially with addition of intermediate substrates. These results suggested that substantial amounts of methane are only produced when fresh plant material is amply available. Recalcitrant peat plays only a subordinate role even it is carbon content is high. Since only little CH4 emission was observed from high carbon content peat soils in this study, it was indicated that the soil carbon of the peat soils may not act as a substrate of CH4. As WFPS of the tropical peat soils are high, CH4 fluxes also tended to become higher. This result indicated that WFPS control methane producing activity by creating anaerobic environment. However, WFPS also showed a significant negative relationship with MPN of methanotrophs. This result indicated a possibility of methane oxidation activity of the peat soils controlled CH4 fluxes as affected by WFPS. Results of incubation experiment showed CH4 production only in treatment D: incubating the peat soils supplied with litter in flooded condition (Fig. 1). However, CH4 oxidations were more intense than CH4 production in the other treatments. It is interesting to note that even in flooded treatment: incubating soil under flooded condition, the CH4 concentration in the head space of the test tubes kept being lowered for 4 weeks. These results suggested that the soil organic carbon of recalcitrant organic matter did not behave as substrates of methanotrophs intensely. Besides, without intact photosynthetic products such as litter, CH4 production could not be intense as CH4 oxidation even the peat soils were flooded.

Conclusions

Although the peat soil consists of organic matter, this recalcitrant organic matter would not act as substrate of CH4 or reinforce of CH4 oxidation. Because of low CH4 producing activity of the peat soils, methanotrophs‘ activity in the environment would be controlled by WFPS by adjusting oxygen supply into the peat soils.

Acknowledgement

We thank the staffs of the University of Palangka Raya to support the field observation described in this paper.

References

Furukawa Y, Inubushi K, Ali M, Itang AM, Tsuruta H 2005: Effect of changing groundwater levels caused by land-use changes on greenhouse gas emissions from tropical peatlands. Nutr. Cycl. Agroecosys., 71, 81-91.

Hadi A, Inubushi K, Furukawa Y, Purnomo E, Rasmadi M, Tsuruta H 2005: Greenhouse gas emissions from tropical peatlands of Kalimantan, Indonesia. Nutr. Cycling Agroecosys., 71, 73-80.

Hirano T, Segah H, Harada T, Limin S, June T, Hirata R, Oosaki M 2007: Carbon dioxide balance of a tropical peat swamp forest in Kalimantan, Indonesia. Glob. Change Biol., 13, 412-425.

Inubushi K, Hadi A, Okazaki M, Yonebayashi K 1998: Effect of converting wetland forest to sago palm plantation on methane gas flux and organic carbon dynamics in tropical peat soil. Hydrol. Process, 12, 2073□2080

Inubushi K, Furukawa Y, Hadi A, Purunomo E, Tsuruta H 2003: Seasonal changes of CO2, CH4, and N2O fluxes in relation to land-use change in tropical peatlands located in coastal area of South Kalimantan. Chemosphere, 52, 603-608.

Joosten H, Couwenberg C 2009: Are emission reductions from peatlands MRV-able? Wetlands International, 14p.

Melling L, Hatano R, Goh KJ 2005: Methane fluxes from three ecosystems in tropical peat of Sarawak, Malaysia. Soil Biol. Biochem., 37, 1445–1453.

Saitoh S, Iwasaki K, Yagi O 2002: Development of a new most-probable-number method for enumerating methanotrophs, using 48-well microtiter plates. Microbes. Environ., 17, 191-196.

Segers R 1998: Methane production and methane consumption: a review of processes underlying wetland methane fluxes. Biogeochem., 41, 23–51.

Takakai F, Morishita T, Hashidoko Y, Darung U, Kuramochi K, Dohong S, Limin SH, Hatano R 2006: Effects of agricultural land-use change and forest fire on N2O emission from tropical peatlands, Central Kalimantan, Indonesia. Soil Sci. Plant Nutr., 52, 662-674.

Toma, Y., Takakai, F., Darung, U., Kuramochi, K., Limin, S.H., Dohong, S., Hatano, R., 2011. Nitrous oxide emission derived from soil organic matter decomposition from tropical agricultural peat soil in central Kalimantan, Indonesia. Soil Sci. Plant Nutr., 57, 436–451.

Wösten JHM, Clymans E, Page SE, Rieley JO, Limin SH 2008: Interrelationships between peat and water in a tropical peatland ecosystem in Southeast Asia. Catena 73, 212–24.

Air pollution affected by peat and forest fires in Central Kalimantan

Izumi Noguchi[1)]*, Hiroshi Hayasaka[2)], Nobumasa Sekishita[3)], Aswin Usup[4)]

[1)] Institute of Environmental Sciences, Hokkaido Research Orgnization, Sapporo, Japan.
[2)] Hokkaido University, Sapporo, Japan.
[3)] Toyohashi University of Technology, Toyohashi, Japan.
[4)] Palangka Raya University, Palangka Raya, Kalimantan Tengah, Indonesia.

*E-mail address: izumi@hro.or.jp

An air pollution survey was conducted at an urban site in Palangka Raya and a rural site in a suburb of Palangka Raya during the dry seasons of 2010, 2011, and 2012.
Our measurement results in the rural site showed: atmospheric concentrations of sulfur dioxide, sulfate, nitrate, elemental carbon, organic carbon, potassium, nitric acid were strongly affected by wild fires. Furthermore, the concentrations of nitrogen dioxide, nitrous acid, and ammonia were also affected by only near wild fires. However, the same pollutants were found to be higher at an urban site than those at a rural site, likely caused by a variety of city emissions. Since fine particle components, such as ammonium sulfate, are easily transported across wide areas, their concentrations seemed to be of the same magnitude between both sites.

Keywords: Air pollution, gas, particle, wild fire, Kalimantan.

Introduction

There are vast tropical peat marsh forests in central Kalimantan, Indonesia. Dry season peat and forest fires have occurred frequently after the implementation of an agriculture policy called the "Mega-rice project." The fires must be controlled to lessen impacts on human health, natural resources, greenhouse gas emissions, and so on.

The Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA) are involved in a project aimed at global warming mitigation and prevention through development of an integrated carbon management system to help control the carbon dioxide emitted from these forests. This study is one component of this project. Its goal is to estimate the effects of tropical wild fires on human health and to sound a warning for the prevention of wild fires.

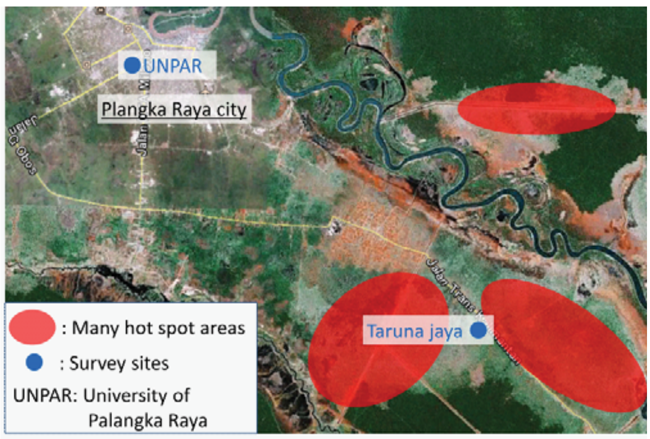


Fig. 1 Sampling sites.

Sampling and Method

An air pollution survey was conducted at an urban site and at a rural site, as shown in Figure 1. The urban site was located in central Palangka Raya city, at the University of Palangka Raya (UNPAR). The rural site was located at a suburb of Palangka Raya city, Taruna jaya. Wild fires were observed frequently around Taruna jaya during the dry season.

Wild fires were not observed in 2010, but were observed often around both sites in 2011. In 2012, fires were observed in the southern area, far from Taruna jaya.

The filter-pack method (FP) and the passive sampler method (PS) were the chosen methods for this study, as shown in Figure 2 (EANET, 2003; Noguchi et al., 2007). Both methods are used by international air pollution monitoring networks such as EANET (Acid Deposition Monitoring Network in East Asia).

Chemical analysis was conducted following collection. Elemental carbon (EC), organic carbon (OC), particle ion components (SO42-, NO3-, Cl-, F-, Na+, K+, Mg2+, Ca2+ and NH4+), sulfur dioxide (SO2), nitric acid (HNO3), nitrous acid (HONO), and ammonia (NH3) were measured by FP. Nitrogen dioxide (NO2) was measured using PS.

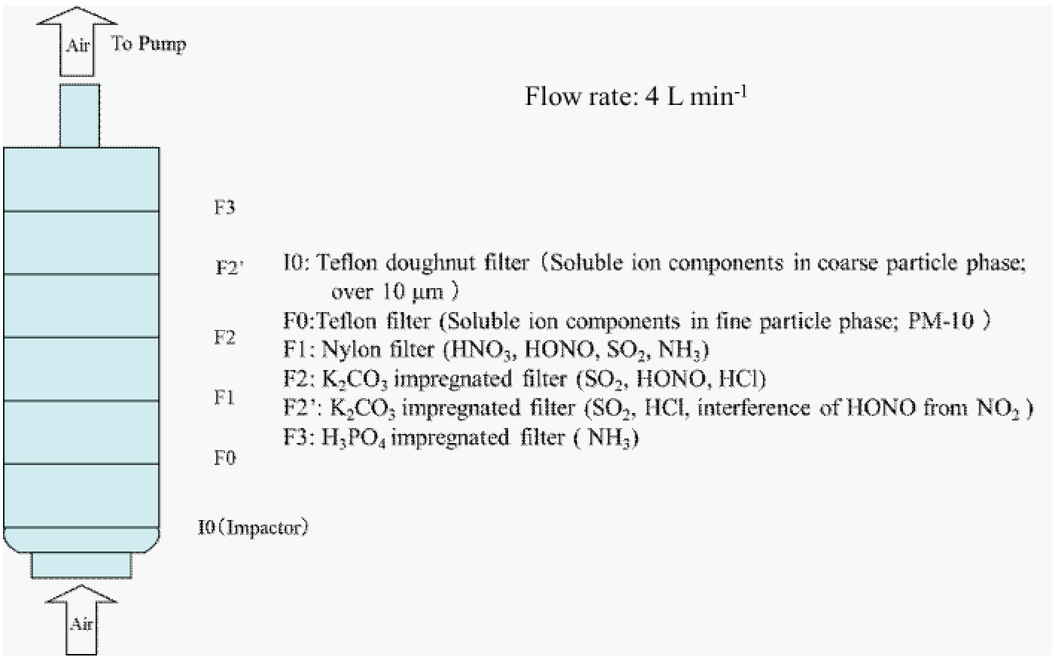


Fig.2 Filter-pack method (EANET, 2003; Noguchi et al., 2007).

Results and Discussion

The observed air pollutant concentrations are shown in Table 1, with ratios in comparison to each term and site shown in Table 2.

As per our results, 2011 concentrations of SO2 and SO42- (indicators of peat fire), NO3-, EC, OC, K+, and HNO3 (indicator of biomass burning) were higher than those in 2010 and 2012 at Taruna jaya. It was suggested that these air pollutant concentrations were affected by an increase in wild fires.

In addition, particulate component concentrations were also higher than that of gas components, where concentrations of SO42- were larger than SO2 concentrations. Furthermore, the concentrations of SO42-, K+, and NH4+ were also relatively high in East Asian records (EANET, 2012: 2013), save for the 2010 Taruna jaya record, when no fire was present. Wild fires seemed to be the largest emitters of particulate pollutants.

Table 1 Air pollutant concentrations.

Site	Data set	SO_2	HNO_3	HONO	HCl	NH_3	NO_2	SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	EC	OC
		n mol m^{-3}															μg m^{-3}	
Taruna jaya	19-24 Sep. 2010	5.3	4.6	12.8	3.0	327.3	64.5	14.3	0.9	0.9	12.7	1.7	3.2	0.1	0.1	2.3	1.8	6.8
	15-22 Aug. 2011	15.6	16.5	21.6	29.8	643.5	176.2	86.3	4.8	5.0	72.4	11.2	24.6	0.3	0.8	6.1	5.0	28.2
	29 Aug.-5 Sep. 2012	12.7	11.2	10.9	16.9	318.7	68.6	76.9	2.0	1.6	75.7	5.2	12.6	0.5	0.6	3.0	3.0	16.5
UNPAR	17-22 Aug. 2011	39.4	13.9	28.5	61.0	1239.6	273.1	114.0	15.3	30.6	141.1	13.0	31.3	0.4	0.9	11.8	6.0	87.9
	29 Aug.-5 Sep. 2012	13.5	15.9	12.3	33.1	328.5	110.0	77.2	3.4	3.3	71.2	7.5	15.1	0.4	0.7	3.4	2.8	22.5
	UNPAR: University of Palangka Raya																	

Table 2 Air pollutant concentration ratios.

Site / Data set	SO_2	HNO_3	HONO	HCl	NH_3	NO_2	SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	EC	OC
2011 Taruna jaya/2010 Taruna jaya	3.0	3.6	1.7	9.8	2.0	2.7	6.0	5.3	5.4	5.7	6.6	7.6	2.4	6.3	2.7	2.8	4.1
2012 Taruna jaya/2010 Taruna jaya	2.4	2.4	0.9	5.6	1.0	1.1	5.4	2.2	1.7	6.0	3.0	3.9	4.6	4.7	1.3	1.7	2.4
2011 UNPAR/2011 Taruna jaya	2.5	0.8	1.3	2.0	1.9	1.5	1.3	3.2	6.2	1.9	1.2	1.3	1.5	1.1	1.9	1.2	3.1
2012 UNPAR/2012 Tarna jaya	1.1	1.4	1.1	2.0	1.0	1.6	1.0	1.7	2.1	0.9	1.4	1.2	0.8	1.2	1.1	0.9	1.4
2011 UNPAR/2012 UNPAR	2.9	0.9	2.3	1.8	3.8	2.5	1.5	4.5	9.4	2.0	1.7	2.1	1.0	1.3	3.5	2.1	3.9
UNPAR: University of Palangka Raya																	

The concentrations of HONO, NO2, and NH3 in 2011 are higher than those recorded in 2010. The concentrations reported in 2012 are of the same magnitude as 2010. These results indicate that wild fires were the prominent cause of air pollution at Taruna jaya in 2011. The effects of wild fires in 2012 seemed to be negligible for HONO, NO2, and NH3 because the fire was located far from Taruna jaya. Moreover, it should be noted that the NH3 concentrations were higher than other gases and particulate components. Those concentrations were relatively high in East Asian records (EANET, 2012: 2013) despite a lack of fire in 2010.

Concerning survey results obtained at the city site, UNPAR, the concentrations of many components are higher than those observed at Taruna jaya. This is caused by the variety of emissions located within the city. However, particle components such as (NH4)2SO4 seemed to be of the same magnitude, or exhibited only minor differences between both sites. The concentrations of SO42- and NH4+ are similar between 2011 hot spot conditions, and 2012 far from hot spot conditions. It is recognized that those fine particulates are easily transported across a wide area. In addition, fine particulate such as PM2.5 is also easily absorbed into the lungs and has a high risk for human health. Thus, the human health risk is equally high both inside and outside fire areas. Wild fire control is also important for the protection of human health.

Conclusions

An air pollution survey was carried out at UNPAR in Palangka Raya city in 2011 and 2012 and Taruna jaya, which is a suburb of Palangka Raya city, in 2010, 2011, and 2012. The survey results follow:

1. Atmospheric concentrations of SO2, SO42-, NO3-, EC, OC, K+, and HNO3 were affected prominently by wild fires.
2. The concentration of particulate components is higher than that of gas components.
3. The concentrations of HONO, NO2, and NH3 were also affected by only near wild fires.
4. The concentrations of many components at UNPAR are higher than those at Taruna jaya because of the variety of emissions located within the city.
5. Particle components such as (NH4)2SO4 seemed to be of the same magnitude or exhibiting only minor differences between UNPAR and Taruna jaya. Thus, it was recognized that these fine particulates easily carry over a wide area.

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References

Noguchi, I., Otsuka, H., Akiyama, M., Sakai, S., Kato, T. (2007). Measuring Concentrations of Nitrous Acid Gas by the Filter- Pack Sampling Method. Journal of Japan Society for Atmos. Environ., 42, 162-174 (in Japanese).

EANET (Acid Deposition Monitoring Network in East Asia) (2003). Technical Document for Filter Pack Method in East Asia. http://www.eanet.asia/product/index.html (last access 31/10/2013).

EANET (Acid Deposition Monitoring Network in East Asia) (2012). Data Report on the Acid Deposition in the East Asian Region 2010. http://www.eanet.asia/product/index.html (last access 31/10/2013).

EANET (Acid Deposition Monitoring Network in East Asia) (2003). Data Report on the Acid Deposition in the East Asian Region 2011. http://www.eanet.asia/product/index.html (last access 31/10/2013).

Analysis of regional groundwater movement in the Block-C North Area (2): water budget and groundwater level decrease in the drought period

Hiroshi Fukami[1)]*, Ken Koizumi[2)], Yoshiyuki Ishii[3)], Koichi Yamamoto[4)], Hideaki Nagare[5)], Hidenori Takahashi[6)], Suwido H. Limin[7)], Kitso Kusin[7)], Adi Jaya[7)], Untung Darung[7)], Aswin Usup[7)], Kaharap[7)] and Gatot Eko Susilo[4), 8)]

[1)] Geological Survey of Hokkaido, Sapporo, JAPAN
[12)] Nippon Koei Co., Ltd., Tokyo, Japan
[3)] Institute of Low Temperature Science, Hokkaido University, Sapporo, JAPAN
[4)] Yamaguchi University, Ube, JAPAN
[5)] Okayama University, Okayama, JAPAN
[6)] Hokkaido Institute of Hydro Climate, Sapporo, JAPAN
[7)] University of Palangka Raya, Palangka Raya, INDONESIA
[8)] Lampung University, Lampung, INDONESIA

* E-mail address: fukami-hiroshi@hro.or.jp

One of the main objectives of the Block-C team of the Carbon Management 1-1 group is to clarify the hydrological characteristics of peatland in the Block-C North area by field observations and simulation models. The purposes of this paper are to discuss about the water budget of peat layer, and the groundwater level decrease in the drought period, using the simulation model of regional groundwater flow for this area. The main results are summarized as follows: The main recharge component of the shallow aquifer was precipitation. The differences between recharge and discharge were lower compared to the total amounts at the end of the rainy period. Conversely, recharge by precipitation was less during the drought period, and discharge occurred through evapotranspiration. The groundwater level continued decreasing until significant precipitation occurred. We could estimated remarkable groundwater level decreases in relevant locations.

Keywords: peatland, simulation, groundwater level, water budget, drought period.

Introduction

The final goal of the JST-JICA project, "wild fire and carbon management in the peat-forest of Indonesia", is to contribute to preventing global warming by developing an integrated carbon management system to control the carbon dioxide emitted from the tropical peat forests. Research organizations of the project are divided four programs. The carbon management (CM) program is one of them, also divided several groups. The authors belong to the Block-C team of CM 1-1 group which is one of CM groups.

The main objectives of the Block-C team of the CMa 1-1 group are to clarify the hydrological characteristics of the peatland groundwater in the Block-C North area and to evaluate the dam and canal efficiency for maintaining a high groundwater level in peatland, through both field observation and the simulation model.

In Central Kalimantan, Indonesia, massive drainage canal excavation performed during the Mega Rice Project in the late 1990s caused a significant groundwater level decrease and soil drying within the surface peat layer. Many severe wildfires occurred, and their range expanded in every dry year. The area between the Kahayan River and the Sebangau River is called ‘Block C’ of the Mega Rice Project. Our study site is the Block-C North area, located about 15 km southeast of Palangka Raya, Central Kalimantan.

The groundwater and canal water level measurement were started from 2010 in the site (Ishii et al., 2012). The simulation model of regional groundwater flow for Block-C North aria was proposed and calculated the effects of canal excavation and evaluation of dam construction (Koizumi et al., 2013). The purposes of this paper are 1) to clarify the water budget of peat layer, and 2) to confirm the groundwater level decrease in the drought period, using the simulation model. The monthly water budget was derived at 2011 when severe wild fire did not occur. The hydrological condition was simulated at 2009 when severe wild fire occurred, and the water budget was derived as same way. A 90-day no-rain period was also simulated into the 2011 drought period, and compared with 2009 condition.

Study site and method

Groundwater and canal water level measurements

There are two main drainage canals in Block-C North area constructed with the Mega Rice Project: the Kalampangan Canal and the Taruna Canal. The Kalampangan Canal connects with shortest line between the Kahayan River and the Sebangau River. On the other hand the Taruna Canal starts at the junction with the Kalampangan Canal to the southeast direction.

To determine the present groundwater condition, we constructed 32 observation wells for shallow groundwater (5 m in depth), 6 wells for deep groundwater (20 m in depth) and 13 canal water level measuring sites, and installed water level data loggers to the all sites from 2010. The weather station is located at the Base Camp of the University of Palangka Raya adjacent the bridge of Trans-Kalimantan Road across the Kalampangan Canal. These observation sites are shown in Figure 1. The coordinates and altitude for all sites are determined by the static GPS survey in 2010 and 2011 (Yamamoto et al, 2011).

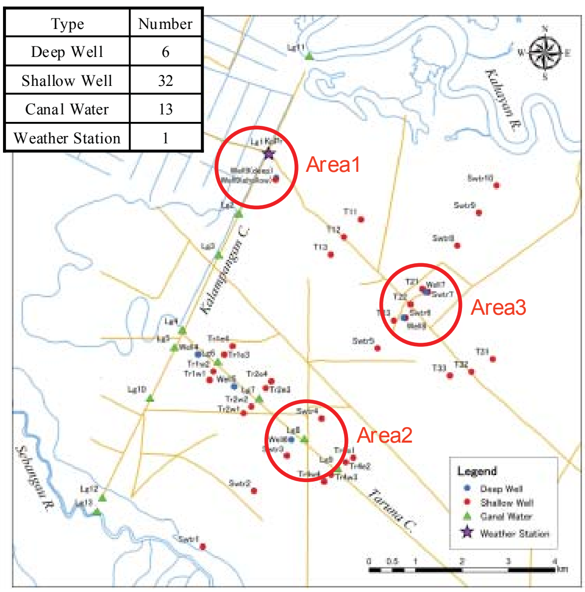


Figure 1. Water level observation sites and weather station in Block-C North area. Red circles from Area 1 to Area3 are intoroduced in Figures 3 and 4.

From these observations, it confirmed that peatland in the Block-C north area is dome shaped, and that an aquitard existed below the peat layer. This aquitard separates the deeper sand layer as the confined aquifer from the peat layer (unconfined aquifer) in nearly the entire study area. Figure 2 is the proposed hydro-geological model for the Block-C North area. The groundwater levels in the peat layer are affected by precipitation. Conversely, the groundwater levels in the deeper sand layer do not affected by precipitation, and are lower than those in the peat layer at same place in the drought period. The groundwater level fluctuations in the deeper sand layer mainly depend on river water level fluctuations.

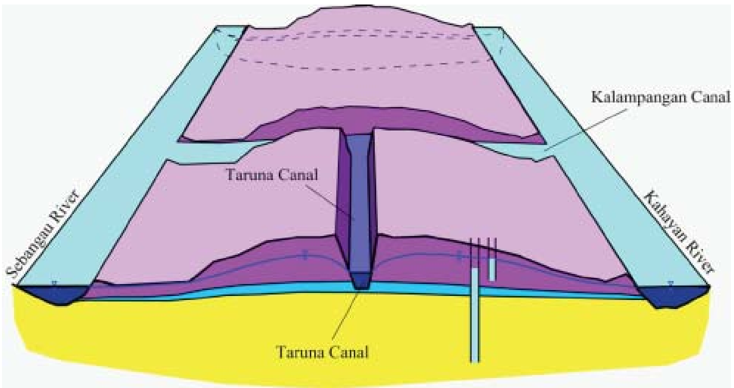


Figure 2. Schematic diagram of hydrogeology in Block-C North area.

Numerical simulation

We applied MODFLOW as a regional groundwater flow model to simulate the present groundwater flow conditions from 2010 to 2012, based on measured results mentioned above. The details of simulation model are described in Koizumi et al. (2013), and the consistency and accuracy of the model are also confirmed using the time series groundwater level fluctuations for two aquifers by Koizumi et al. (2013).

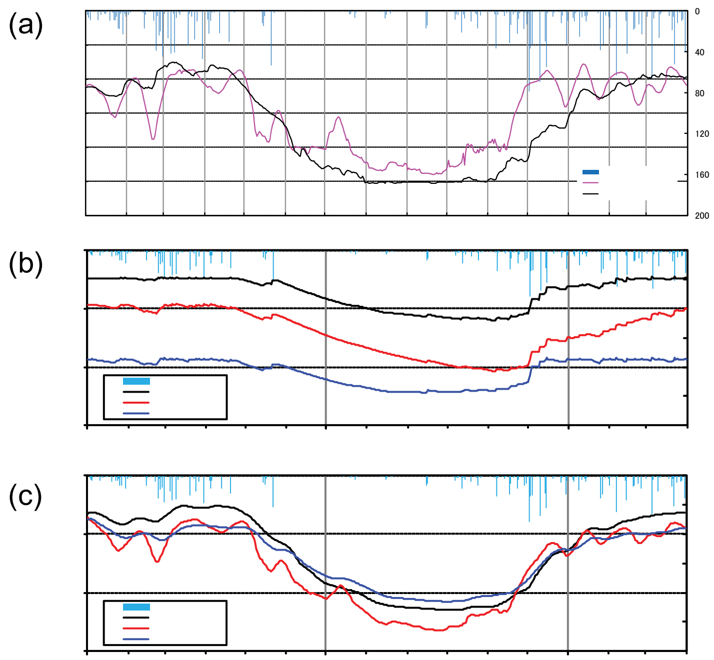


Figure 3. Result of 2011 simulation (from January 2011 to March 2012).
Red,black and blue lines in (b) and (c) are Area 1, 2, and 3 in Figure 1

The results of 2011 are summarized in Figure 3. Upper part (a) of this figure is precipitation (time series input value) and river water level variations (time series boundary conditions) at the Kahayan River (Lg 11) and the Sebangau River (Lg 13), middle part (b) shows the calculation results of the time series groundwater level fluctuations in the peat layer (shallow aquifer), and bottom part (c) shows those in deeper sand layer (deep aquifer). In (b) and (c) of Figure 3, the difference of line colour indicates the position of red circles in Figure 1.

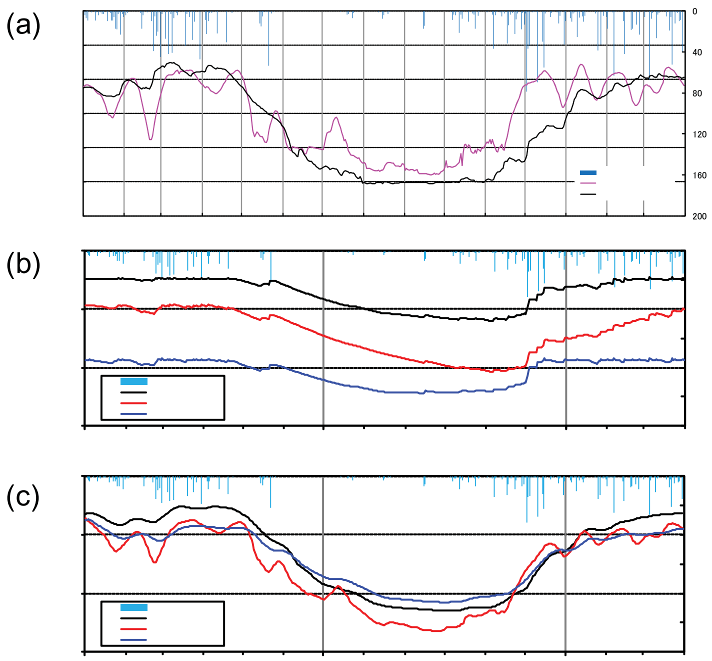


Figure 4. Result of 2009 simulation (from January 2009 to March 2010).
Red,black and blue lines are same as Figure 3.

The calibrated model was applied during the 2009 drought period when a severe wildfire occurred and the groundwater level decrease in shallow aquifer was examined in the drought period. The results of 2009 are shown in Figure 4 as same as Figure 3. Since there were no data about the river water level in the case of 2009, the values of the upstream observation results at Lg 11 and Lg 13, respectively. The river water levels were corrected and adopted.

Result and discussion

Water budget

In the simulation of the recharge to the shallow aquifer, the tank model was used for representing the recharge process for surface and unsaturated layer. Conceptual diagram of the recharge process is shown in top part of Figure 5. The precipitation is loosed by the evapotranspiration (ET) and the surface outflow in this process, and the remainder affects the groundwater recharge. The monthly water budgets for the shallow aquifer were estimated in both 2009 and 2011, separating surface recharge model (Figures 6 and 7). The rechargecomponent which was described in figure 5 was used for the drought period, shown in the right sides of those figures.

From the simulations and water budgets of 2011 and 2009 conditions, the results are summarized in the following points:

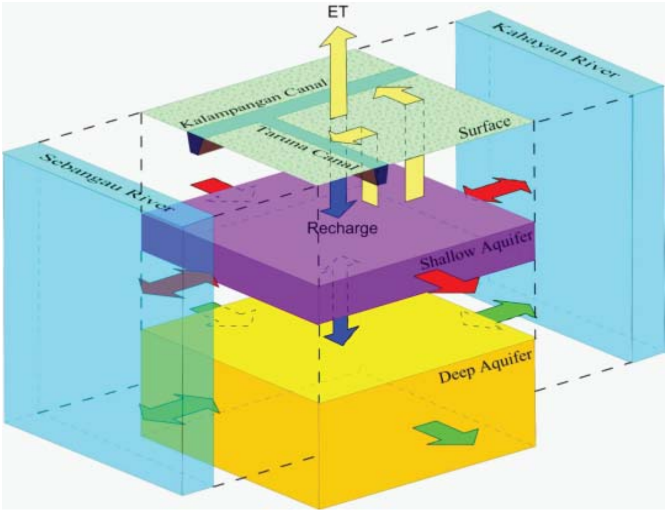


Figure 5. Conceptual diagram of water budget for shallow aquifer

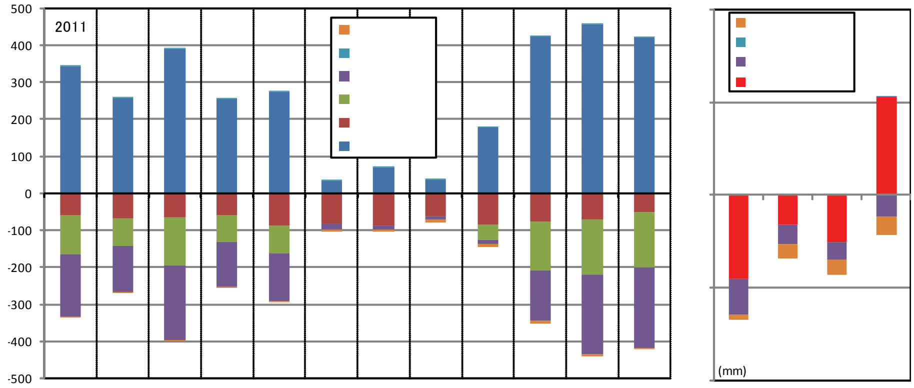


Figure 6. Monthly water budget in 2011.
Right side shows the drought period from June to September, enlarging vertical axis.
Recharge = Orecipitation - Evapotranspiration - Surface flow, in top part of Figure 5.

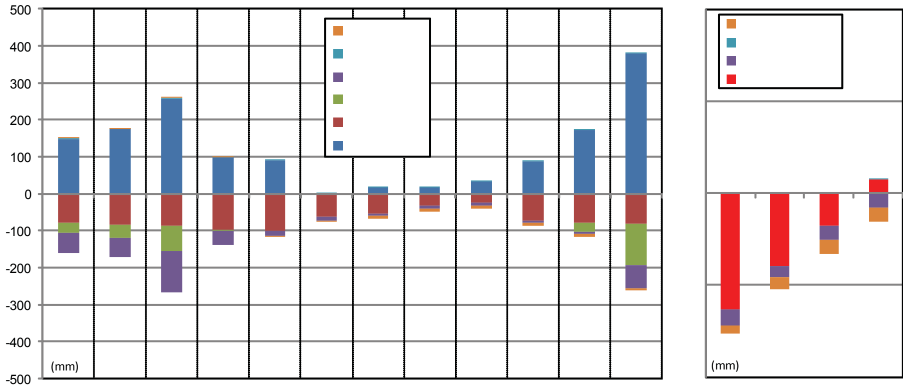


Figure 7. Monthly water budget in 2009 (shown same as Figure 6).

1) The main recharge component of the shallow aquifer was precipitation. In the rainy period, surface outflow, river outflow, and evapotranspiration were main discharge components. The composition ratio of discharge depended on precipitation. The differences between recharge and discharge were lower compared to the total amounts at the end of the rainy period for both years.

2) Conversely, recharge by precipitation was less during the drought period, and discharge occurred through evapotranspiration. Because the water budget became negative, the groundwater level of the shallow aquifer decreased. A small amount of precipitation that occurred did not contribute to the groundwater level increase. When conditions of no precipitation continued into the 2009 drought period, evapotranspiration decreased. The groundwater level also continued decreasing until significant precipitation occurred.

Groundwater level decrease in the drought period

A 90-day no-rain period was simulated into the 2011 drought period, and the time series groundwater level fluctuations in the shallow aquifer were compared with the actual case (Figure 8). When no rain condition continued, it was simulated that the groundwater level in the shallow aquifer decreased larger and longer.

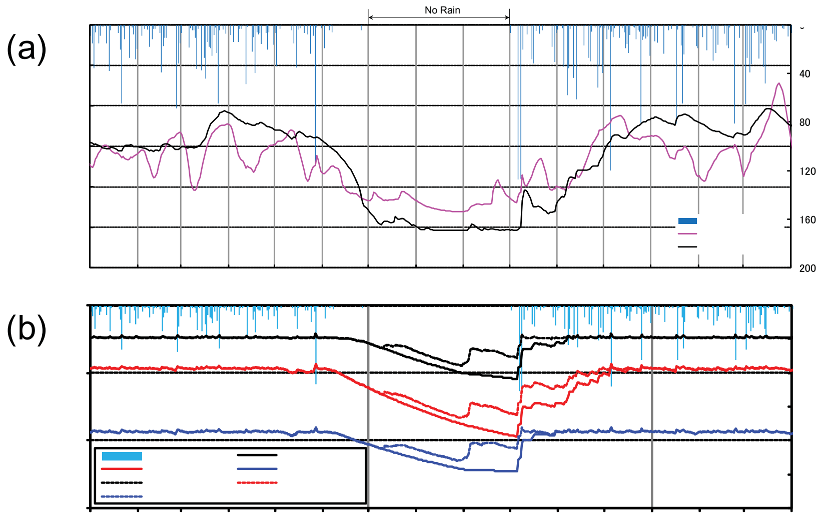


Figure 8. 90-day no-rain period simulation into 2011 drought period.
(a) and (b) are same as Figure 3.

Solid line indicates 90-day no-rain simulation, and dotted line indicates the actual case.

The decreasing amounts of the groundwater levels in the shallow aquifer were calculated during the drought periods for 2009, 2011 and 90-day no-rain period simulation. The result is shown in Figure 9. It was confirmed that the groundwater level in shallow aquifer at the case of 90-day no-rain period decreased similar to 2009 case. And we estimated the remarkable groundwater level decreases in relevant locations, and confirmed that the risk of wildfire increased near the canal.

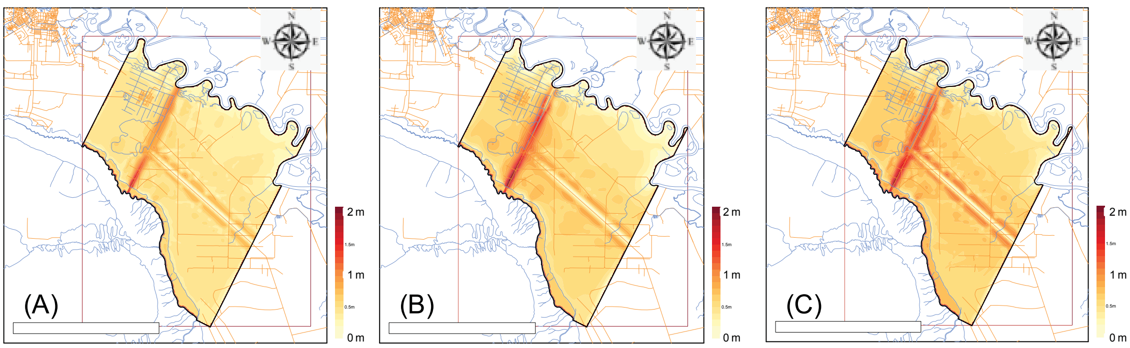


Figure 9. Decreasing amout of groundwater level during drought period.
(A), (B) and (C) indicate 2011 case, 2009 case, and 90-day no-rain case, respectively.

Concluding remarks

In this paper, we discussed about the water budget of peat layer (shallow aquifer) and the groundwater level decrease in the drought period, using the simulation model of regional groundwater flow for Block-C North area. The results are summarized as followings:

1) The main recharge component of the shallow aquifer was precipitation. The composition ratio of discharge depended on precipitation. The differences between recharge and discharge were lower compared to the total amounts at the end of the rainy period. Conversely, recharge by precipitation was less during the drought period, and discharge occurred through evapotranspiration. A small amount of precipitation did not contribute to the groundwater level increase. The groundwater level continued decreasing until significant precipitation occurred.
2) A 90-day no-rain period was simulated in the 2011 drought period. In this case, the groundwater level of the shallow aquifer decreased similar to 2009. We could estimate the remarkable groundwater level decreases in relevant locations, and confirmed that the risk of wildfire increased.

The relation between no-rain period and groundwater level decrease will be estimated at any location by the simulation. We were already simulated the groundwater level change before the canal construction. We will be able to calculate the water budget in the drought period before the canal construction.

Acknowledgement
This study was carried out as a part of the research project, "Wild Fire and Carbon Management in Peat-Forest in Indonesia" supported by the JST-JICA. The authors would like to thank many stuffs and members of the project for their useful suggestions and assistances.

References

Ishii, Y., Fukami, H., Koizumi, K., Yamamoto, K., Nagare, H., Thakahashi, H., Limin, S. H., Kusin, K., Jaya, A., Darung, U., Usup, A., Kaharap and Susilo, G. E.(2012). Characteristics of regional groundwater movement and its modelling in the block-C North area. Proceedings of 3rd International Workshop on Wild Fire and Carbon Management in Peat-Forest in Indonesia, Palangka Raya, Indonesia, 22-24 September 2011, 146-152.

Koizumi, K., Ishii, Y., Fukami, H., Yamamoto, K., Nagare, H., Thakahashi, H., Limin, S. H., Kusin, K., Jaya, A., Darung, U., Usup, A., Kaharap and Susilo, G. E.(2013). Analysis of regional groundwater movement in the Block-C North area: present, past and future. Proceedings of International Symposium on Wild Fire and Carbon Management in Peat-Forest in Indonesia, Bogor, Indonesia, 13-14 September 2012, pp.184-196.

Yamamoto, K., Ishii, Y., Fukami, H., Koizumi, K., Nagare, H., Takahashi, H., Limin, S.H.,Kusin, K., Adi Jaya, Darung, U., Usup, A., Kaharap & Gatot, E.S. (2011). Survey in the Kalampangan Canal for the clarification of the groundwater movement and the effect of the dam construction. Proceedings of 2nd International Workshop on Wild Fire and Carbon Management in Peat-Forest in Indonesia, Palangka Raya, Indonesia, 28-29 September 2010, pp.194-202.

Remote sensing of CO_2 to evaluate the CO_2 emission from forest/peat-land fires

G. Inoue[1)], M. Kawasaki[2)], M. Ohashi[3)], M. Yamaguchi[4)], K. Yamaguchi[4)],
T. Asanuma[4)], S.Tsubokura[4)], K. Yoshikawa[5)], K. Shibata[5)], Y. Matsubara[5)],
T. Abe[5)], M. Evri[6)]. and A. Sulaiman[6)], A. Usup[7)] and A. Hadi[8)]

[1)] University of Tokyo,
[2)] Nagoya University
[3)] Kagoshima University
[4)] Meisei Electric Co.
[5)] Sumitomo Corporation
[6)] BPPT
[7)] University of Palangka Raya
[8)] Universityof Lambung-Mangkurat

Due to its portability in field measurement, the FES-C instrument was used to measure CO2 emission from widely spread and less predictable local sources such as forest/peatland fires near Parangka Raya in the dry season of 2011.

Key words: MRV, fiber optical components, latent flux method, hot spots

Method

We describe a compact instrument for measuring atmospheric CO2 columns,1 utilizing commercially available fiber optics and a fiber Fabry-Perot interferometer (Meisei Electroric. , model FES-C). Wilson et al.2 reported a CO2 column spectrometer, in which they used conventional optics and a solid glass Fabry-Perot interferometer. In our FES-C instrument, sunlight is collimated through an optical filter by a fiber collimator installed on a small sun tracker, and then, is split into two optical components. One component is a FES-C for CO2 spectrum analysis and the other is a reference detector for correcting the spectrum intensity due to solar intensity fluctuation. The CO2 rotational lines centred at 1572 nm are analysed with the FES-C that has a temperature coefficient toward the transmittance wavelength. This allows the solar light wavelength passing through the FES-C is able to be on- and off-aligned with the CO2 rotational lines by controlling the FES-C temperature. The I0 and I values in the Beer-Lambert law equation are deduced by modulating FES-C temperature in 40 s/cycle, which allow measurement of xCO2 with the precision of 1.3 ppm under clear sky condition.3

We have reported about a similar instrument for measuring atmospheric CO2 columns at surface monitoring sites, which consists of a solar telescope attached on a sun tracker and a commercial desktop optical spectrum analyser (OSA, model AQ6370, Yokogawa Meters & Instruments) that resolves the rotational lines of CO2 in 30 s/scan and is basically maintenance free for self-calibration and self -alignment.2,5 The practical usefulness at a surface monitoring site was examined in parallel with a high resolution Fourier transform spectrometer (FTS) situated at the University of Wollongong in Australia. Averages of the OSA and FTS column densities measured during July–October were (8.369±0.087)× 021 and (8.413±0.056)×1021 molecules cm−2, respectively, a ratio of 0.995 and thus in good agreement.

Results and Discussion

Due to its portability in field measurement, the FES-C instrument was used to measure carbon emission from widely spread and less predictable local sources such as forest/peatland fires. As schematically explained in Fig. 1, the local flux of CO2 is measurable if a CO2 observation network is constructed to surround the target emission area, and air transfer data are obtained. We performed a campaign using the FES-C instruments in the central Kalimantan of Indonesia as a part of measurement- reporting- validation (MRV) activities for carbon emission reduction. In this campaign, two sets of the FES-C instruments were deployed parallel to the predominant wind direction at Banjar Baru and Palangka Raya in Kalimantan, respectively. Two months of column data were automatically obtained as shown partially in Fig. 2. During Aug. 24-26 when big fires were detected in MODIS satellite data, large differences in the xCO2 data between two observation sites are noticed. The CO2 emission between the observation sites may be evaluated after factoring the xCO2 difference by the wind flux.

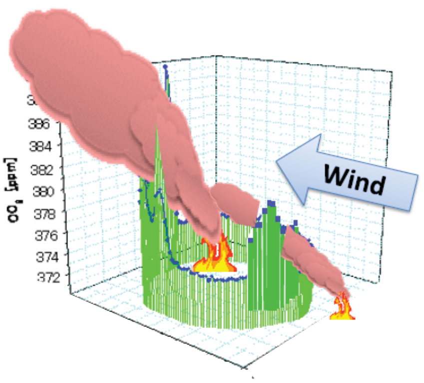


Fig. 1. Schematics of the latent flux method for estimating total amounts of CO2 emitted from a targeting area. Vertical bars indicate xCO2 mixing ratios measured by an observation network that surrounds the targeting area where forest/peatland fires occur. By factoring the difference in CO2 mixing ratios at out- and in-flow points, along with fluxes of air mass, the total amount of CO2 emitted in the area is known.

During the dry season of El Ninõ years, large-scale forest/peatland fires occur, e.g. 1997 -1998, it was estimated that 0.81–2.57 Gt of carbon was emitted in the entire Indonesian archipelago. This wide range in the numbers reflects uncertainty in conventional estimation methods. In reviewing and implementing the MRV activity, it is important to establish an operating structure to implement the monitoring, especially in light of this situation where there has not yet been enough data collected to quantitatively assess the emissions.

This work is sponsored by JICA-JST and GRENE-ei programs.

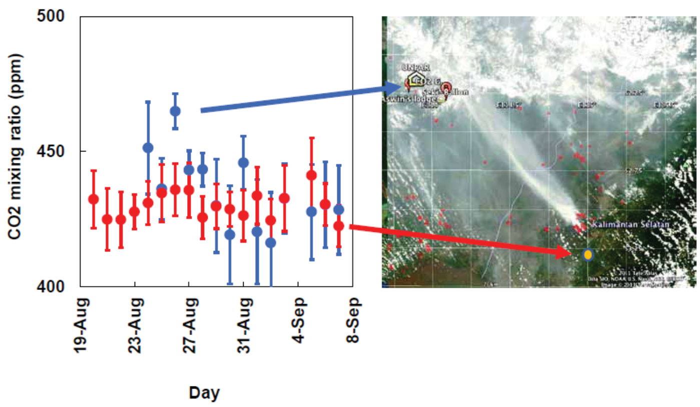


Fig. 2. Variation of day-averaged CO2 mixing ratios (ppm) measured at two cities apart by 95 km, Parangka Raya S2.12º E113.54º and Banjar Baru S3.26º E114.50º, in Kalimantan of Indonesia when forest/peatland fires occurred in Aug. 20th – Sept. 5th of 2011. The MODIS satellite image of NASA, USA, shows huge white smoke caused by fires on Aug. 25, 2012. Red dots on the image denote hot spots.

References:

N. Kobayashi, G. Inoue, M. Kawasaki, H. Yoshioka, M. Minomura, I. Murata, T. Nagahama, Y. Matsumi, T. Tanaka, I. Morino, T. Ibuki,, Atm. Measure. Tech., 3, p. 1103, 2010, doi:10.5194/amt-4-1103-2010

E.L. Wilson, E. M. Georgieva, W. S. Heaps, Meas. Sci. Technol. 18, 1495, 2007

M. Kawasaki, H. Yoshioka, N. B. Jones, R. Macatangay, D. W. T. Griffith, S. Kawakami, H. Ohyama, T. Tanaka, I. Morino, O. Uchino, T. Ibuki, Atm. Measure. Tech. 5, 2593, 2012, doi:10.5194/amt-5-2593-2012

Influence of sampling method on the physical characteristics of peat

Hirochika Hayashi[1)]*, Mitsuhiko Kamiya[2)], Koichi Ikeda[3)],
Hiroshi Shimokura[4)], Noriyoshi Ochi[5)] and Hidenori Takahashi[6)]

[1)] Civil Engineering Research Institute for Cold Region, Sapporo, Japan
[2)] Ueyama Shisui Co., Ltd., Sapporo, Japan
[3)] Hokkaido Dositsu Consultant Co., Ltd., Sapporo, Japan
[4)] Nippon Koei Co., Ltd., Tokyo, Japan
[5)] Nippon Koei Co., Ltd., Sapporo, Japan
[6)] Hokkaido University, Sapporo, Japan

* E-mail address: hayashi@ceri.go.jp

This paper discusses the applicability of two undisturbed sampling methods for peat soil using a sampling rate as a measure of applicability, and the influence of four sampling methods on the physical characteristics of peat.

Keywords: peatland, physical characteristics, sampling, geotechnical investigation.

Introduction

Carbon dioxide emissions from tropical peatland in Indonesia are associated with the lowering of ground water levels caused by development in the region. The main factors behind such emissions are the break-up of peat due to land dehydration and loss of peat due to fires. Accordingly, groundwater management is a crucial consideration in the conservation of tropical peatland and the formulation of carbon management guidelines. The authors discussed the management of peatland groundwater based on the construction of a series of weirs in the Kalampangan Canal located in Indonesia's Central Kalimantan region (Ochi et al., 2012).

Information on the geotechnical properties in this region is necessary for weir construction. However no previous studies have sought to elucidate these properties. To clarify the situation, undisturbed samples need to be collected. This also applies to the measurement of carbon levels in peat.

Against such a background, peat was sampled at the Takahashi site in the Kalampangan area, Central Kalimantan of Indonesia using four sampling methods: the undisturbed sampling methods of thin-walled tube with fixed piston sampling in accordance with the Japanese Geotechnical Society's standard (JGS method: JGS, 2004) and the Indonesian Institute of Sciences method (LIPI method), and the disturbed sample methods of peat sampling and post-hole auger boring (auger sampling). The differences in physical characteristics of the peat samples were analysed. This paper discusses the applicability of two undisturbed sampling methods for peat soil using sampling rate as a measure of applicability and the affect of four sampling methods on the physical characteristics of peat.

Investigation site and methods

A geotechnical investigation was carried out at the Takahashi site in the Kalampangan area of Central Kalimantan, Indonesia. Using the four methods shown in Table 1, peat was sampled at the site from 2010 to 2013. Figure 1 shows setup of the JGS method.

Laboratory tests on the peat samples were conducted to investigate the physical characteristics such as natural water content, ignition loss and dry density.

disturbed/undisturbed	sampling method	abbreviated nama
disturbed	peat sampling	—
	post-hole auger sampling	auger sampling
undisturbed	Indonesian Institute of Sciences method	LIPI method
	thin-walled tube sampling with fixed piston	JGS method

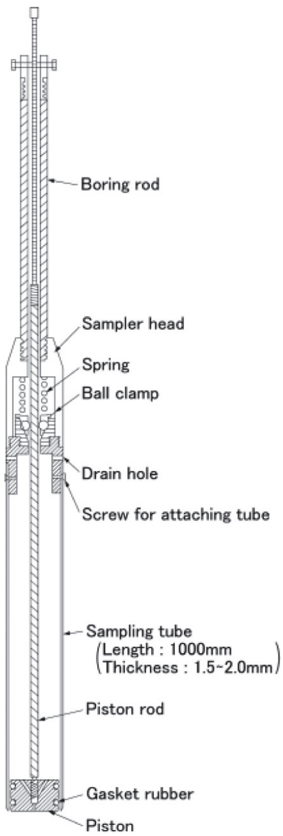


Figure 1. Thin-walled tube sampler with fixed piston used (JGS method)

Test results and discussion

Sampling rate of undisturbed samples

This section discusses the applicability of the two undisturbed sampling methods (JGS method and LIPI method) for peat soil. In March 2011, peat was sampled undisturbed at the Takahashi site using the LIPI method. In September 2013, peat was sampled undisturbed at the same site using the JGS method.

Table 2 shows the maximum penetration depths of the samplers, the total lengths of the collected samples and the sampling rate R defined by Eq. (1), where, Lc is the length of the collected sample (m) and Dd is the depth of penetration (m).

Table2. Sampling method used

sampling method	max. depth of penetration	total legth of collected sample	Sampling Rate *R*
peat sampling	3.75m	—	—
auger sampling	4.60m	—	—
LIPI method	3.05m	1.84m	60%
JGS method	3.53 m	3.21 to 3.50m	91 to 99% (ave. 96%)

In both sampling methods, sampling was carried out up to the depth reachable by manual penetration force. At this level of penetration force, the JGS method achieved deeper penetration than the LIPI method. A high sampling rate is also a measure of the applicability of a sampling method for peat soil. The JGS method's sampling rate (96% on average) was higher than that of the LIPI method (60%). From the above two factors, it can be determined that the JGS method is highly useful to the LIPI method for the undisturbed sampling of peat soil.

Problems with the LIPI method are as follows;

(1) Penetration generates high friction, since multiple polyvinyl chloride (PVC) pipes are connected and pushed into the ground.
(2) Due to the thick wall of the edge of the sampling tube that is made of PVC pipes with a diameter of 10 cm, the penetration resistance is high.
(3) The in situ soil is compressed when penetrated, because the penetration speed is slow.
(4) The sampling rate decreases at muddy layers, because of the compression.

Photo1. Peat sample being pushed out of the sampling tube (GL-1.13m to 1.22m)

Next, the sampling conditions under the JGS method, which was found to be higher applicability, are described. Photo 1 shows a portion from 1.13 m to 1.22 m below Ground Level (GL) of a peat sample being pushed out of the sampling tube. After the portion approximately 10 cm long was pushed out and cut off by a cutter, its length and mass were measured for calculation its density. Photo 2 shows the conditions of a sample at 2.35 m to 2.4 m below GL. In Photo 2, the natural water content of the sample was a very high 1290%; therefore, the sample was so fragile that it crumbled immediately after being pushed out of the tube. In light of the above, the length was measured while the sample was supported by human hands. Photo 3 shows the typical woody peat that was often found at the investigation site. Woods decomposed to this extent could be cut with the edge of the sampler used for the JGS method. The above fact proves the applicability of the JGS method for woody peat as well, such as the peat soil at the investigation site.

(a) Sample in the tube

(b) Sample pushed out of the tube

Photo 2. Conditions of a sample (GL- 2.35 m to 2.4 m)

Photo 3. Typical woody peat found at the investigation site

Ignition loss

Figure 2 shows the depth distribution of the ignition loss of peat samples collected by a peat sampler and by an auger sampler as well as by the previously mentioned two kinds of samplers. It should be noted that, since there were differences in elevation among the investigation points, the depths were adjusted to enable comparison under the same conditions. Sampling by peat sampler (March 2010) and by auger boring (March 2012) used manual penetration. However, since the auger can be driven into the ground by hammering, it was able to penetrate deeper: up to the clay layer, with a penetration depth of 4.6 m. In contrast, the peat sampler could be pressed up to a depth of 3.75 m due to its thin diameter, and samples could be extracted from a layer with an approximate water content of 100%.

It should be noted that, since the LIPI method compresses samples, it is not possible to match sample lengths with actual penetration depths. Even so, judging from the ignition loss, it is reasonable to believe that the penetration reached a depth of roughly 3.7 m, the same depth achieved by auger boring.

In addition, since the ignition loss was around 100% in most cases, it can be presumed that the peat deposited in an aquatic environment where sediment movement was inactive. The bottom peat layer was white clay at the Takahashi site and black sand at Dam 3 in the Kalampangan canal 500 m from the Takahashi site.

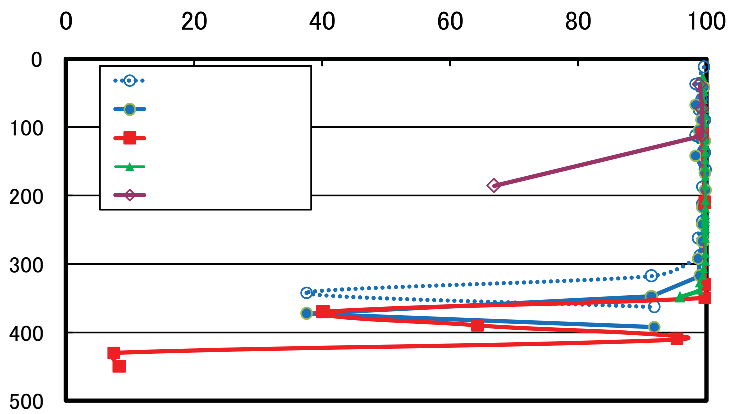


Figure 2. Depth distribution of the ignition loss of peat samples

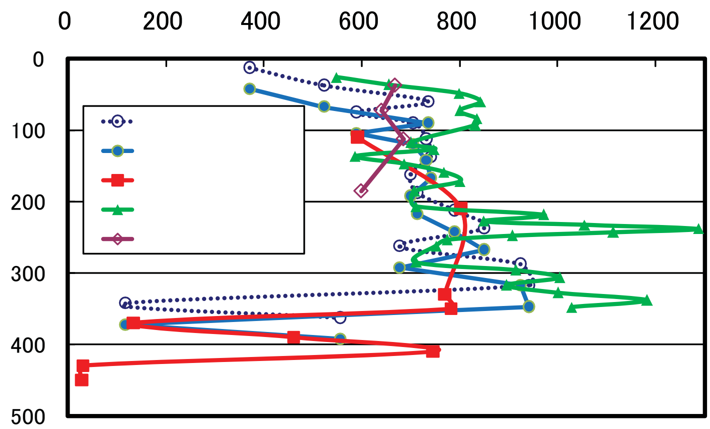


Figure 3. Depth distribution of the natural water content of peat samples

Natural water content

Figure 3 shows the depth distribution of natural water content. The natural water content of samples collected by the JGS method are relatively high. The natural water content of samples collected from the muddy layer shown in Photo 2 exceeds 1000%. As factors behind this, we can assume that, with the use of a peat sampler, the soil is compressed when penetrated, and the soil around the outer periphery of the sampler is scraped off, causing peat compression that results in a decreased water content. The same is true for the auger sampling: The water content is lowered by disturbance. From the above, it can be predicted that the water content of the sample taken by disturbed sampling is lower than that taken by undisturbed sampling.

Dry density

Figure 4 shows the depth distribution of dry density. The dry density is distributed between 0.08 and 0.15 g/m3and averages 0.115 g/m3, while the wet density is between 0.97 and 1.48 g/m3 and averages 1.07 g/m3. The dry density tends to decrease with increase in depth, and no increase in density by consolidation is observed. In the LIPI method, density comparison in terms of depth is not possible, since the collected samples are compressed, but the density shows relatively high values, averaging 0.13 g/m3.

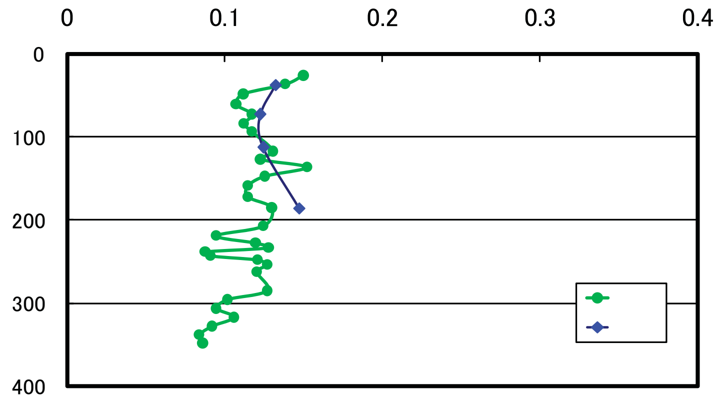


Figure 4. Depth distribution of the dry density of peat samples

Figure 5 shows the relationship between the natural water content and the dry density. This includes investigation results collected from other sites, such as the Kalampangan Canal. The curved line in the figure represents the relationship between the above two under saturation, calculated by the following procedure using the natural water content and the ignition loss.

(1) The ignition loss corresponding to each specific natural water content is found by using Eq. (2), where, w: natural water content (%), Lig: ignition loss (%) and f: coefficient (assumed to be 10 based on the peat in Hokkaido).

$$w = f \cdot Lig \qquad (2)$$

(2) Regarding peat as a mixture of minerals and organic matter, the density of soil particles is found by Eq. (3) using the ignition loss, where, ρs: density of soil particles, ρsm: density of the mineral part of peat (=2.7) and ρso: density of the organic part of peat (=1.5).

$$\rho_s = \frac{\rho_{sm} \cdot \rho_{so}}{(\rho_{sm} - \rho_{so}) Lig / 100 + \rho_{so}} \qquad (3)$$

(3) Assuming saturated conditions, the dry density ρd is calculated by using Eqs. (4) and (5), where, e: void ratio, Sr: degree of saturation (assumed to be 100% since it is at the groundwater level), ρw: water density and ρd: dry density.

$$e = \frac{w \cdot \rho_s}{S_r \cdot \rho_w} \qquad (4)$$

$$\rho_d = \frac{\rho_s}{1 + e} \qquad (5)$$

Values represented by this curved line are approximated to the measured values throughout the line. Therefore, the dry density can be estimated by measuring the water content of peat at or below the groundwater level.

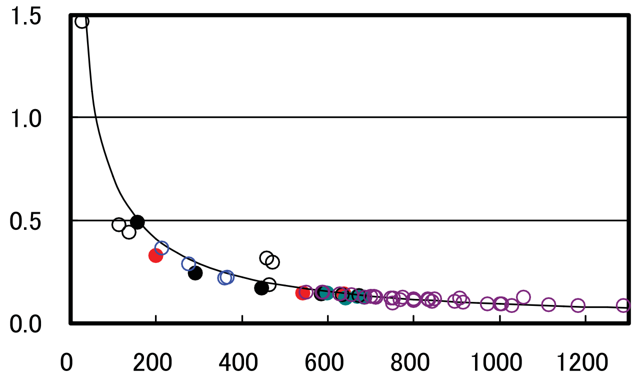


Figure 5. Relationship between the natural water content and the dry density

Summary

1) The sampling ratio of the JGS method at the Takahashi site averages 96%, higher than that of the LIPI method. Therefore, the JGS method is more applicable for woody peat soil, such as that of the investigation site.
2) The JGS method enables sampling even at a muddy layer where sampling is not possible by a peat sampler.
3) The natural water content of samples collected the JGS method from the muddy layer is higher than that of samples taken by a peat sampler.
4) The dry density at the Takahashi site measures between 0.08 and 0.15 g/m3, with the value decreasing with increase depth.
5) A simple method to estimate the dry density from the water content is proposed.

References

Japanese Geotechnical Society (2004). Japanese Standards for Geotechnical and Geoenvironmental Investigation Methods –Standards and Explanations-, 194-200 (in Japanese).

Ochi N., Shimokura H., Okada M. and Kamiya M. (2012). Arrangement and Structure of Weirs in Kalampangan Channel, Proceedings of 3rd International Symposium on Wild Fire and Carbon Management in Peat-Forest in Indonesia.

Carbon storage of a peat swamp forest after fire and land use change - a case study of 16-year (1997-2013) change in the Lahei District, Central Kalimantan, Indonesia

Akira Haraguchi[1)]* and Tatsuyuki Seino[2)]

[1)] Faculty of Environmental Engineering, The University of Kitakyushu, Japan
[2)] Tsukuba Experimental Forest, Agricultural and Forestry Research Center, Faculty of Life and Environmental Sciences, University of Tsukuba, Japan.

* E-mail address: akhgc@kitakyu-u.ac.jp

Changes in carbon storage within a forest research plot in Lahei district, Central Kalimantan, that was established in 1997 have been investigated with reference to the history of forest fire and land use change. The former kerangas forest plot had burned completely in 2002 and then burned two times in 2004. About 2/3 area of the plot where litter accumulated over sand horizon in the area has been converted to karet plantation since 2006. Averaged peat layer thickness in this 1-ha plot was 9.5 cm in 1997 and that in 2013 was 9.4 cm. This implies that the peat layer has been scarcely disturbed by the intensive forest fire and the following repeated fires if hydrological condition of peat was not changed e.g. by drainage.

Keywords: land use change, Lahei, peat accumulation.

Introduction

Peat swamp forests accumulates so huge amount of carbons both in vegetation and in peat layers, and hence the destruction of peat swamp forests means the intensive emission of carbon to the atmosphere and the consequent progress of global climate changes. Forest fire is one of the serious factors promoting carbon emission to the atmosphere directly by the transformation of organic carbon to carbon dioxide. Some burned forested areas, caused by irrespective of artificial or natural fire, have been transformed to agricultural fields. Estimation of carbon accumulation as well as balance between production and decomposition are the important information in order to make an appropriate management procedure for the transformed land or to make a plan to develop pristine forests under the balance between protected forests and transformed lands from the global climate point of view. However, accumulated data on the carbon budget of the peat swamp forest focusing on the vegetation change before and after forest fires and/or land transformation are not enough. This study provide a case study on carbon accumulation change in a peat swamp forest that was transformed to the rubber plantation after the serious fire by comparing the data in 1997 and 2013.

Study area and research site

Two forest research sites were established in 1997 in Lahei district, Central Kalimantan, Indonesia. One plot in the kerangas forest (plot 1; 1.0 ha, 2148 individuals; 1.9245°S, 114.1724°E) was established on shallow peat deposited on sand layer accompanying dried litter layer with rhizosphere of shrub species on the forest floor. The plot had burned completely in 2002 and then burned twice in 2004. About 2/3 of the plot 1 has been converted to the karet (Hevea brasiliensis; Euphorbiaceae) plantation since 2006. Secondary forest with canopy height of ca. 10 m has been revegetated on the remaining part of the plot 1. The other plot was established in the pristine peat swamp forest (plot 2; 1.0 ha, 1653 individuals; 1.9313°S, 114.1804°E) with maximum peat depth of ca. 7.5 m (Haraguchi et al., 2001) and the plot has never been disturbed by fire since 1997.

Changes in carbon accumulation in forest

Changes in carbon accumulation within a forest research plot 1 (kerangas forest) in Lahei district have been investigated with reference to the history of forest fire and land use change. The former kerangas forest used for the karet plantation was burned during the process of land use change. The litter layer has completely burned because the layer consists of inflammable organic materials, and sand layer appeared at the surface after burning of the litter layer. A secondary forest established on parts of the area with peat accumulation at present.

Biomass of karet plantation in the plot 1 was estimated by using the formula proposed by Ketterings et al. (2001). There were 154 individuals of karet plant within the plot 1 in 2013, and the biomass was estimated to be 2.15 ton/ha, corresponding to 1.08 C ton/ha. Biomass of the former forest within plot 1 was 216.43 ton/ha in 1998 (Kohyama et al., 1999). Above ground carbon accumulation in the area that has been converted to karet plantation significantly decreased.

Changes in peat accumulation

Litter layer with high air space was inflammable and then the kerangas forest including plot 1 was burnt down at the intensive fire in 2002. Litter layer did not remain at all in 2013, whereas peat remains at the same area as investigated in 1997. Averaged peat layer thickness in this 1-ha plot was 9.5 cm in 1997 and that in 2013 was 9.4 cm. This implies that even after the burned down of above ground vegetation as well as litter layer of the kerangas forest, peat layer remains even if the original peat deposition was shallow before fire. Thus we conclude that the peat layer has been scarcely disturbed by the intensive forest fire in 2002 and the following repeated fires if hydrological condition of peat was not changed (e.g. by drainage). Thus hydrological management would be important for the prevention of forest fire as well as revegetation after forest fire.

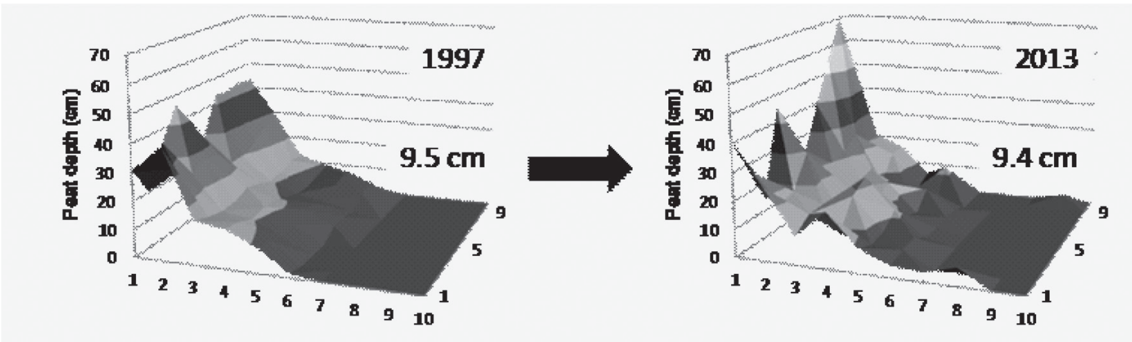


Figure 1. Distribution of peat depth of the Lahei forest research plot 1 (kerangas forest plot) in 1997 and 2013. The x and y axis denote the position in a 100 x 100 m2 plot. Irregular change of peat depth from 1997 to 2013 would be due to the error of data sampling, however the averaged peat depths within the plot in 1997 and 2013 were almost the same.

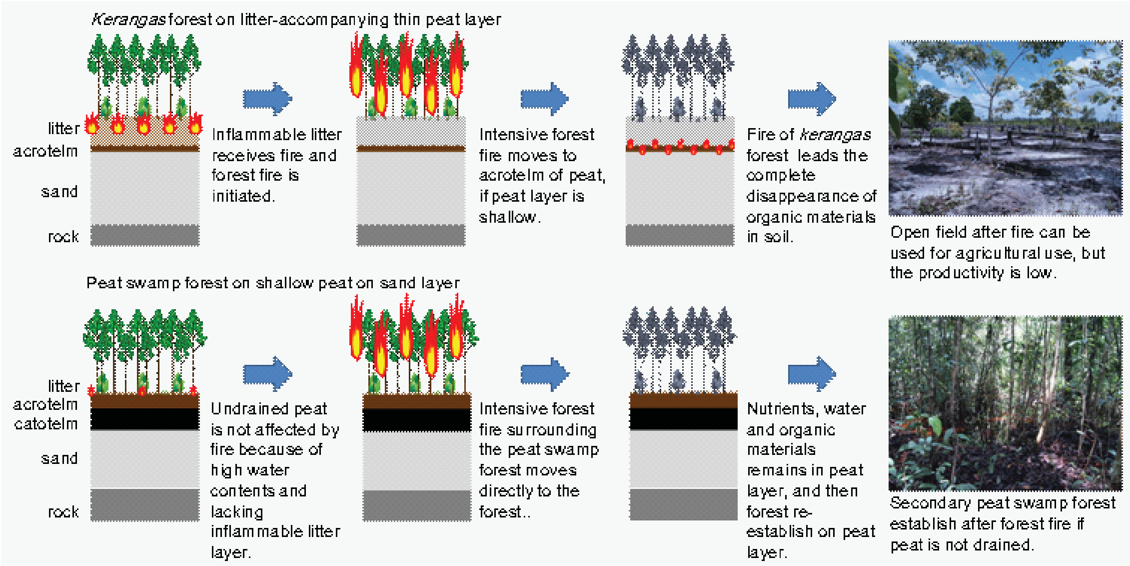


Figure 2. Process of vegetation change of kerangas peat forest after intensive forest fire.

Vegetation change after forest fire

The plot 1 in the former kerangas forest had burned completely and about 2/3 area of the plot 1, litter accumulated over sand horizon in the area, has been converted to karet plantation. Secondary forest with canopy height of ca. 10 m has been revegetated on the peat deposited site (ca. 1/3 of the plot) in the plot 1. The remaining peat would promote revegetation after fire, and then management of peat would be important for re-establishment of forests after forest fire.

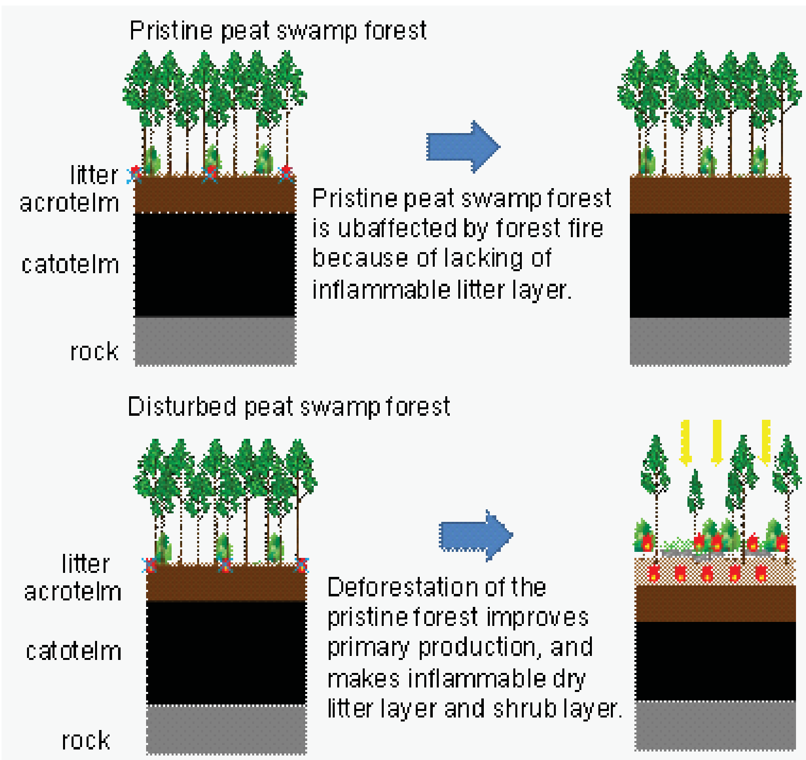


Figure 3. Vulnerability of peat swamp forest by fire before and after deforestation.

The pristine forest including plot 2 established on the well developed peat layer of ca. 7.5 m thickness (maximum) and litter accumulation on the peat was < 10 cm. The site was lacking inflammable dried litter layer, and then the forest has never been affected by intensive fire. Deforestation of the pristine peat swamp forest makes the gaps, and the improved primary production makes inflammable dry litter layer and shrub layer. And then the disturbed forest is vulnerable to fire.

References

Haraguchi A, Shimada S, Takahashi H (2000) Distribution of Peat and its Chemical Properties around Lahei in the Catchment of the Mangkutup River, Central Kalimantan. TROPICS, 10: 265-272

Ketterings QM, Coe R, van Noordwijk M, Ambagau Y, Palm CA (2001) Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. Forest Ecology and Management 146: 199-209

Kohyama T, Suzuki E, Aiba S, Seino T (1999) Functional differentiation and positive feedback enhancing plant biodiversity. In: Kato, M., eds. The Biology of Biodiversity. pp. 179-191. Springer-Verlag, Tokyo.

Miyamoto K, Rahajoe JS, Kohyama T, Mirmanto E (2007) Forest Structure and Primary Productivity in a Bornean Heath Forest. BIOTROPICA 39: 35–42

The prospect of *shorea balangeran* as agroforestry species on peat swamp land (review of silvicultural aspect)

Purwanto B Santosa, Tri Wira Yuwati, Dony Rahmanady, M Abdul Qirom, Marinus K Harun
Banjarbaru Forestry Research Institute, South Kalimantan

pur_balitaman@yahoo.com

Agroforestry in peat swamp land plays a strategic role in the rehabilitation of degraded peat swamp land. Agroforestry was made to enhance the environmental condition while at the same time gaining local income. Shorea balangeran is a commercial timber species of Dipterocarpaceae family known locally as kahoi, kahui or balangeran. It is naturally distributed in groups. The height of balangeran tree could reach up to 20-25 m with the free-branched height of 15 m, diameter 50 cm and has no buttress. The timber has durability class of II and strength class of II and bulk density of 0.86. The, price of balangeran timber is considered expensive of 3 million rupiahs per m3. This paper presented the silvicultural aspect of balangeran as agroforestry plants.

Key words : peat swamp land, agroforesty, Shorea balangeran.

Introduction

The forestry development era nowadays is plantation forest era as main supplier of timber following the lack of supply of timber from natural forests. Natural forests could no longer the national need of timber supply up to 57.1 million m3 per year while natural and plantation forests could only supply 45.8 million m3 per year (MENLH, 2007). Based on strategic plan of Forestry Research and Development Agency (FORDA), plantation forests played role in providing 75% of wood industry in 2014 (FORDA, 2009).

One way to increase the productivity of degraded peat swamp forest land is through plantation. Agroforestry is a mixture between forestry and agricultural plants that contributes in the increasing the productivity of degraded peat swamp forest land. Harun (2005) stated that there were several agroforestry techniques used by local people in the peat land of South Kalimantan namely: alley cropping with mounding, alley cropping with long mounding, alley cropping with sunken bed and multiple cropping with mounding.

Agroforestry in peat land is expected to provide economical, ecological and social benefit to the people. Economically, agroforestry in peat land is expected to supply food and its product diversification for commercial and subsistence use. The availability of tree as a component in peat land agroforestry could become a source for timber and form of investments to farmers.

Shorea balangeran is a commercial tree species of the Dipterocarpaceae family known as kahoi, kahui, balangeran in Kalimantan and belangeran, belangir, belangiran, melangir in Sumatera. In the natural distribution, belangeran is available in groups. The height of balangeran tree could reach up to 20-25 m with the free branched height of 15 m, diameter 50 cm and no buttress. The timber has durability class of II and strength class of II and bulk density of 0.86. The price of balangeran timber in Palangkaraya up to April 2013 is considered expensive of 3 million rupiahs per m3. Nevertheless, the belangeran timber in market currently is taken from natural forests and not yet from plantations. This paper aims to provide information on the silvicutural aspect of Shorea balangeran; a prospective species to be developed as agroforestry plant in peat land.

Methods

The methods used in this paper were results of desk study of Banjarbaru Forestry Research Institute results of Shorea balangeran silvicultural aspects including: nursery and seedling growth, land preparation, planting, tending and root development.

Result and Discussion

1. Nursery and the growth of seedlings

The fruiting seasons of balangeran in the South and Central Kalimantan was February to April. The specified months of 2011 was Shorea balangeran mega harvesting time. The number of balangeran seeds per kilogram was 3,500-4,000 seeds per kilogram. Balangeran seeds was recalcitrant so that the seeds could not be stored in long time. Thus, belangeran seeds should be directly sown in polybags or seed beds and stored in the shape of seedlings and not seeds.

Vegetative propagation of balangeran by controlling the environment by fogging system (KOFFCO-Komatsu FORDA Fog Cooling methods) showed that cuttings was rooting between 11-16 weeks with the survival rate of 75.3% (Rusmana, 2005). The media for cuttings was river sand and mixture of cocopeat and rice husk (2:1) (Rusmana and Lazuardi, 2004).

The increasing of belangeran seedling growth could also be carried out by fertilization and the application of indigenous mycorrhiza explored from peat swamp land. Yuwati et al., (2010) reported that the application of macro nutrients of Urea (N), TSP (P), KCl (K) and Dolomit (CaMg) with the dosage of 36,8 mg/ polybag to balangeran seedlings twice a week could increase the height growth following the application of N, P, K while CaMg had no effect on the height, diameter and number of leaves of 7 months old balangeran in the nursery (Yuwati et al., 2010).

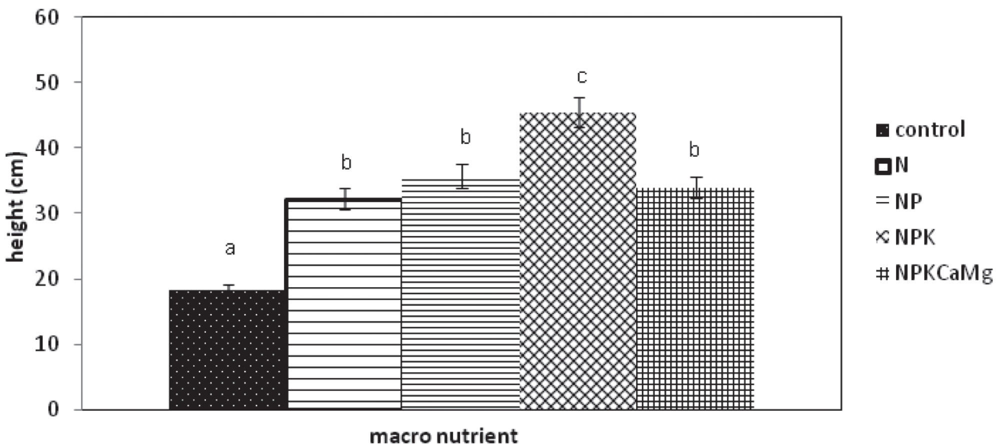


Figure 1. The mean height of S. balangeran seedlings 7 months after N, P, K,CaMg application in the nursery (Yuwati et al., 2010)

The increasing of belangeran seedling growth could also be carried out by fertilization and the application of indigenous mycorrhiza explored from peat swamp land. Yuwati et al., (2010) reported that the application of macro nutrients of Urea (N), TSP (P), KCl (K) and Dolomit (CaMg) with the dosage of 36,8 mg/ polybag to balangeran seedlings twice a week could increase the height growth following the application of N, P, K while CaMg had no effect on the height, diameter and number of leaves of 7 months old balangeran in the nursery (Yuwati et al., 2010).

The application of mycorrhiza was reported by Turjaman et al. (2011) ; ectomycorrhizal spores of Boletus sp. and Scleroderma sp. could increase 26% of the height of belangeran while Strobilomyces sp. could significantly increase 16% the height of belangeran compared with control.

2. Land preparation and planting

Naturally, there were microtopographies of peat swamp forest which were varied in terms of peat surface elevation consisted of hummock and hollow. Hummock is a higher peat surface with height of 0.3-1 m and hollow is a lower peat surface. According to Rieley dan Page (2008), microtopography in peat surface consisted of small hummocks and hollow with height up to 50 cm. Hummock-hollow was altered massively in the peat swamp due to the unwise use of this ecosystem by estabilishing big canals (Anonimous, 2008).

Based on the evaluation of balangeran in the secondary peat swamp forest that was burnt in 1997 in Tumbang Nusa Central Kalimantan showed that plant's height and diameter were better in a higher microtopography (Santosa, 2010b). Belangeran that was planted in hummock showed the best height (13 m) and the lowest height was planted in hollow (5,5 m).

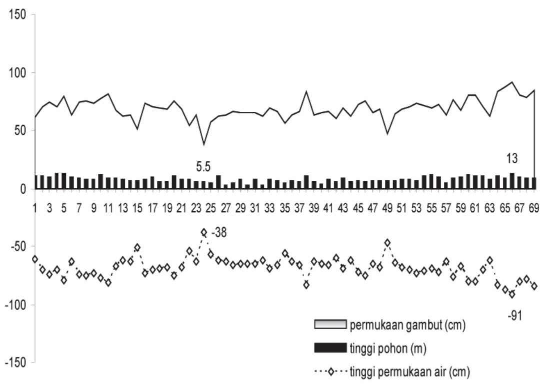


Figure 2a. Microtopography of peat surface (hummocks and hollows) of belangeran plantation (Santosa, 2010b)

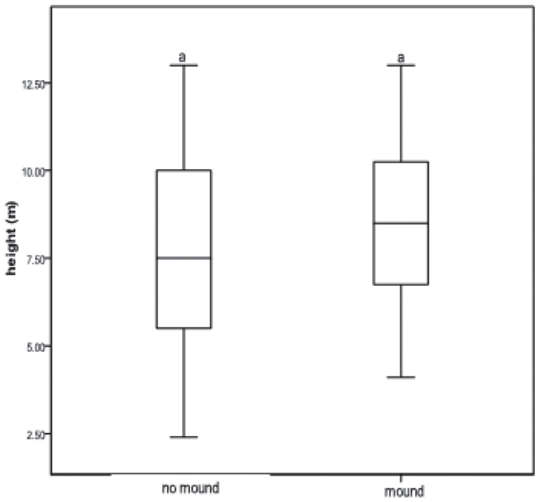
Parameter	Growth		Remarks
	Good	Bad	
Height (cm)	1250 (±50)	270 (±43,5)	sig
Diameter (cm)	14,53 (±1,8)	1,9 (±0,3)	sig
Crown diameter (m)	3,9 (±1,1)	1,2 (±0,3)	ns
Light intensity (%)	0,17 (±0,02)	0,11 (±0,01)	ns
Temperature (^{o}C)	26,5 (±2,1)	29,3 (±0,5)	ns
Humidity (%)	86 (±0,00)	84 (±1,7)	ns
Soil temperature (^{o}C)	26,3 (±0,5)	27 (±0,00)	ns
Fibric content	66,6(±9,4)	68,2 (±12,1)	ns
Microtopography (cm)	12,5 (±4,4)	0,66 (±1,6)	sig
Water table (cm)	75,5 (±4,4)	63,6 (±1,6)	sig

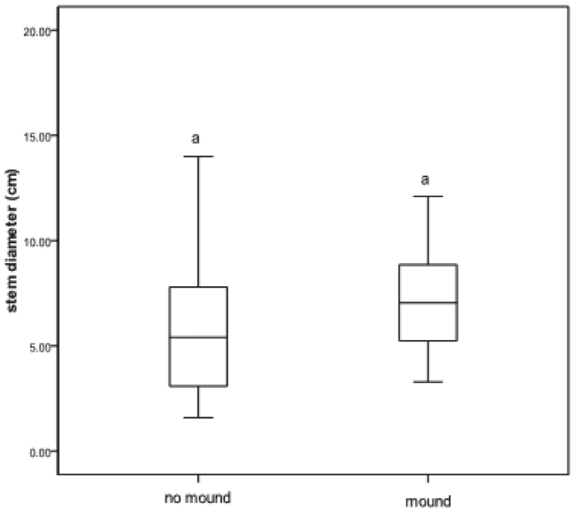
Remark: th number in brackets showed standard deviation

Figure 2b. Environmental condition on belangeran with good and bad performance (Santosa, 2010a)

Based on various observation parameters, there were two significant differences for microtopography and water table parameters. The higher microtopography the lower water table and vice versa.

Based on the measurement of 9.5 year old S. balangeran on two types of land preparation which were with and without mounding showed that mounded and no-mounded balangeran were 8.5 and 8.2, respectively. It means that mounding gave 3.5% better height growth and 8.5% better diameter growth (Figure 3).





The role and effect of mounding of plantation in peat swamp has been reported by several researchers namely:

1) The plantation of Macaranga sp., Baccaurea sp., Syzygium pyrifolium, Sterculia bicolor and Syzygium oblatum on Thailand's peat land showed better growth due to sufficient amount of oxygen in the rooting zone and lesser weeds in the initial growth period (Nuyim, 2000).
2) Mounding was made to avoid inundation and a better aeration while chemically it caused lesser relative acidity and toxicity and higher Nitrogen (Nishimua et al., 2007)
3) Mounding was made to provide a better root environment and to support root anchoring (Aribawa et al.,1993)
4) Reducing impact of inundation on the initial growth of seedlings:
   a. Plants without mounding will experience inundation in their initial growth which led to physiological disturbance such as photosynthesis and carbohydrate transport, macro nutrients absorbance due to decaying of the roots (Kozlowski, 1997).
   b. Innundation could lead to hypoxia and anoxia; which effect the nutrients abosorbance. (Gupta, 2005).
   c. Innundated area caused lack of aeration which will lead to lack of root growth and nutrient absorbance (Sutrisno, 1998).

Those informations emphasized that mounding was a way to avoid inundation in the initial phase of plant's growth.

3. Tending of balangeran

The critical period is a periode where plants in a sensitive condition to environmental variables such as nutrients, water, light and growth space. Weed could disturb the plants in this critical period. The critical period for each species is affected by its ability to compete with weed. The information on critical period of weed competition will be very important to reach efficient weeding. (Sukman nd Yakup, 2002). The plant's growth after bi monthly tending gave the besth mean height growth.

Tabel 1. The effect of tending on the height, diameter and survival rate of S. balangeran (Santosa, et al., 2003)

Tabel 1. The effect of tending on the height, diameter and survival rate of S. balangeran (Santosa, et al., 2003)

Treatment	Growth	
	Height	Diameter
P1	25.32 a	0.20 ab
P2	27.95 a	0.21 a
P3	24.27 a	0.22 b
P0	18.46 a	0.15 a

Remarks :
- The mean followed with the same letter is not significantly different
- P1 = weeding bi-monthly, P2 = weeding once every three months, P3 = weeding once every 4 months, P0 = control.

Belangeran plant's growth showed that plants that were tended once every three months gave the highest height growth compared with bi-monthly, four-monthly and control (no tending for 6 months). The diameter of balangeran showed that there was no significant between treatments. Based on this research, the tending of balangeran could be carried out once every three months. Bastoni and Sianturi (2000) reported that based on the height growth of understorey plants of Sumatera's peat land and the height growth of enrichment plants, tending shall be conducted four-monthly for the first year, six-monthly for the second and third year after planting.

4. The root development of balangeran root

Roots of 9.5 years belangeran were horizontally spread 576 cm with the length of main root of 60cm and the water table of 68.7 - 91 cm. Roots of balangeran spread horizontally while the development of vertical root growth was limited when reached water surface. Nishimua and Suzuki (2007) reported that horizontal distribution of plant's root in peat land indicated that plants absorbed nutrients more effective in the upper layer of peat. Supriyo et al., (2009) presented that Acacia crassicarpa planted in the peat land gave better growth performance in the water depth 80 cm compared with water table < 60 cm five years after planting. Moreover, Supriyo,et al. (2009) emphasized that the availability of oxygen could stimulate the vertical growth of root.

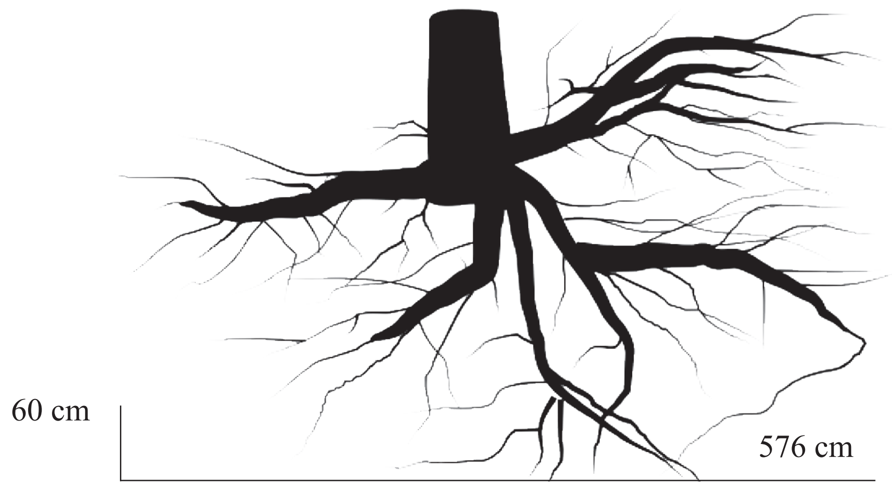


Figure 3. The distribution of belangeran roots

Conclusion

Belangeran grew well in a supportive environmental condition. Therefore, environmental manipulation was needed so that belangeran could grow optimally. In thin and thick innundated peat, site manipulation is needed. Land preparation with mounding individually could increase belangeran's growth. In the application of agroforestry in peat, several techniques that might be applied was alley cropping with mounding, alley cropping with sunken bed and multiple cropping with sunken bed.

Acknowledgement:

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References

Bastoni dan Sianturi, A. 2000. Teknik Penanaman dan Pemeliharaan Tanaman Pengayaan (Enrichment Planting) Pada hutan Rawa Gambut di Sumatera Selatan. Prosiding Seminar Nasional Pengelolaan Hutan Rawa dan Ekspose Hasil-hasil Penelitian Kehutanan di Hutan Lahan Basah dilaksanakan di Banjarmasin. Balai Teknologi Reboisasi Banjarbaru. Pusat Penelitian dan Pengembangan Hutan dan Konservasi Alam, Bogor. P 109-117.

Badan Litbang Kehutanan. 2009. Road Map Penelitian dan Pengembangan Kehutanan. Badan Penelitian dan Pengembangan Kehutanan Jakarta.

Harun, M.K., 2005. Analisis Sosial Ekonomi dan Lingkungan Fisik Sistem Agroforestri Khas Lahan Gambut Tipis di desa Sei Pantai, Kabupaten Barito Kuala, Propinsi Kalimantan Selatan.

MENLH. 2007. Status lingkungan hidup Indonesia 2006. Kementerian Lingkungan Hidup. Jakarta.

Nishimura, T, B., and Suzuki., 2001. Allometric differentiation amoung tropical tree seedling in heat and peat swamp forest. Journal of Tropical Ecology. Hal 667-681.

Rusmana, 2005. Teknik pembuatan bibit sistem KOFFCO. Materi Alih Teknologi Persemaian Sistem KOFFCO. Balai Penelitian Kehutanan Banjarbaru

Santosa, P. B, Yuwati, T. W., and Rachmanadi. D. 2012. Long Term Effect of Site Preparation on the Growth of Balangeran (Shorea balangeran) at Over Burnt Peat Swamp Forest, Central Kalimantan, Proceeding Inafor 2011. Forestry Research and Development Agency. Ministry of Forestry.

Santosa, P.B., Rachmanadi, D., Wahyuningtyas, R. dan Rusmana. 2003. Pengaruh penyiangan gulma terhadap daya hidup dan pertumbuhan awal tanaman Shorea balangeran di lahan rawa gambut. Buletin Tekno Hutan Tanaman (1) : 48-59

Santosa, 2010a. Pertumbuhan Shorea Balangeran (Korth.)Burck.), Gonystylus Bancanus (Miq). Kurz) dan Tetramerista Glabra (Miq.) di Hutan Rawa Gambut Bekas Terbakar Kalimantan Tengah. Tesis. Universitas Gadjah Mada. Tidak dipublikasikan

Santosa, P.B, 2010b. Mikrotopografi, Kedalaman air dan Pertumbuhan Tanaman di Hutan Rawa Gambut. GALAM. Balai Penelitian Kehutanan, Banjarbaru.

Sukman, Y., dan Yakup, 2002. Gulma dan Teknis Pengendaliannya. Raja Grafindo Persada. Jakarta.

Supriyo, H., Nurjanto, H,H., dan Figyantika,A.2009. Effect of water table depht on the root system of Acacia crasicarpa in peat soil (histosols). Proceeding ICBS. Faculty of Biology.Gadjah Mada University.

Rusmana dan Lazuardi,2004. Standardisasi Mutu Bibit. Laporan Hasil Penelitian. Balai Penelitian Hutan Tanaman Indonesia Bagian Timur.

Turjaman, M., Santoso, E., Susanto, A., Gaman, S., Limin, S.H., Tamai, Y., Osaki, M. dan Tawaraya, K. 2011. Ectomycorrhizal fungi promote growth of Shorea balangeran in degraded peat swamp forests. Wetlands Ecology Management 19:331-339.

Turjaman, M., Saito H, Santoso , E., Susanto, A.,Gaman S., Limin S. H., Shibuya M., Takahashi K, Tamai Y., Mitsuru, Osaki and Tawaraya, K., 2008. Effect of ectomycorrhizal fungi inoculated on Shorea balangeran under field conditions in peat-swamp Forests. Proceeding International Seminar Peat. Gadjah Mada University.

Yuwati.T.W., Susanti.P.D., Hermawan.B. 2010. Studi Nutrisi Tanaman Meranti Rawa dan Jelutung Rawa. Hasil Penelitian. Balai Penelitia Banjarbaru. (Tidak dipublikasikan)

Control of Bean Pod Borer Maruca testulalis (Lepidoptera: Pyralidae) with Botanical Insecticides

Melhanah[1)] and Warismun[2)]

[1)] Department of Agriculture, University of Palangkaraya.
[2)] Institute of Plant Protection Food and Horticulture Central Kalimantan Province

E-mail: melhanah@yahoo.co.id

The purpose of this study was to determine the effect of botanical insecticide (tobacco leaf extract and billygoat-weed/babadotan leaf extract) toward the attack intensity of bean pod borer (Maruca testulalis). The study was conducted in the Village Petuk Katimpun, City of Palangka Raya in April to June 2010. The study was using a randomized block design consisting of seven treatments and three replications. The treatments tested were: Without treatment, tobacco and babadotan leaf extract 20, 40.60 g/L of water. The results showed that the application of botanical insecticide were significant effect on the intensity of attack, weight of pods not attacked and attacked and harvest long beans. Botanical insecticide that effectively reduces the intensity of pest attacks M. testulalis in the field is babadotan leaf extract 60 g/L. To reduce the impact on the environment and ecosystems, can use botanical insecticide babadotan leaf extract 60 g/L of water.

Key words: Long beans, Borer, Pod, Insecticides, Botanical.

INTRODUCTION

Long beans (Vigna sinensis L.) is one of the important horticultural commodities, Young pods contain vitamin A, vitamin B and vitamin C. Its seeds contain a lot of carbohydrates, protein, and fat (Nurtika, 1993). Long beans production in 2012 in Palangka Raya 14,060 tons Ha. The production is low, one of the reason is the attack long bean pod borer (Maruca testulalis). Atacks of M. testulalis cause damage an area of 5.4 ha in Palangkaraya, control efforts towards pod borer that has been done so far only using synthetic insecticides (Anonymous, 2013).

The use of synthetic insecticides unwisely can cause undesirable side effects such as the emergence of insect resistance, resurgence, killing natural enemies, and killing other useful insects and environmental pollution (Palm et al, 1970). The alternative is using a botanical insecticide. Leaves of tobacco (Nicotiana tabacum L.) and leaves babadotan/billygoat-week (Ageratum conyzoides L.) can be used as a botanical insecticide (Directorate of Food Plant Protection, 2008). The purpose of this study was to determine the effect of botanical insecticides (tobacco and babadotan extracts) towards intensity of attacks long beans pod borer (M. testulalis).

MATERIALS AND METHODS

The research was conducted in farmers' fields at Cilik Riwut Km. 10, Petuk Katimpun Village, District Jekan Raya, Palangkaraya, Central Kalimantan, from April to June 2010. Research materials are long bean seed varieties Parade, chicken manure fertilizer, Urea, SP-36 and KCl, detergent, water, tobacco and babadotan leaves. The used tools are hoe, hand sprayer,and agricultural equipment supporting this research.

Methods

The study was using a randomized block design consisting of seven treatments and three replications, in order to obtain 21 units of the experiment. The treatments tested were as follows: N0 to N3are without and with tobacco extracts 0; 20; 40; 60 g/L of water and N4 to N6; extract babadotan 20; 40; 60 g/L of water

Implementation Study

Preparation

Soil that has been hoe made 21 plots measuring 2.2 mx 2 m. given chicken dung manure 10 tons / ha (4.4 kg / plot), Urea 150 kg / ha (0.066 kg / plot), SP-36 100 kg / ha (0.044 kg / plot), and 100 kg KCl / ha (0.044 kg / plot). Urea fertilizer is given in two stages, a third dose given at the time of planting and two-thirds of the dose given at 21 days after planting (DAP). SP-36 and KCl are given entirely at the time of planting. Planting seeds long beans in the hole (5 cm), planted at a spacing of 60 cm x 40 cm.

Making and application of botanical insecticides

Leaf tobacco that used sold in the market in the stickform that has been sliced and dried. Babadotan leaves sliced into small pieces, then dried by the sun. Tobacco and babadotan leaves refined until form as flour and ready to use. Tobacco and babadotan flours that taken in appropriate treatment dose is inserted into the measuring cup, then dissolved in 1L of water, added 2 g of solid detergent and precipitated for 24 hours, then filtered to obtain tobacco and babadotan extracts are ready to apply. Botanical insecticide application is done 4 times, at the time the plant was 38 dap, 46 dap, dap 53 and 60 days after planting (DAP).

Observation

Observations were carried out on four plants per plot sample, observed variables include:
a. Attack Intensity of long bean pod borer M. testulalis (%).
Observations were carried out 4 times, at the age of 44, 51, 58 and 65 DAP. The formula used (Directorate of Horticulture, Plant Protection 2007) as follows:

$$P = \frac{A}{N} \times 100\%$$

Description: P = level of pod damage (%), A = number of damaged pods / cluster, N = number of plants / pods were observed.

b. Good pod weight (not attacked) and damaged pod weight (infected) per plot were weighed from the first harvest up to twelve (plant age 45, 48, 51, 54, 57, 60, 63, 66, 69, 72, 75 and 78 DAP) then averaged. Units used are the kg. Harvest per plot (total weight of both good pod and pods damaged) are converted to ton/ hectare. Harvesting is done with harvest interval of 3 days

Analysis of Data

To determine the effect of the treatment, the observations made by analysis of variance F test at level of α = 0.05 and 0.01. If there is an effect of the treatment then continued with HSD test at 5% level.

RESULTS

Intensity of attack pod borer (M.testulalis)

Intensity of attack pod borer after four applications can be seen in Table 1. Application botanical insecticides tobacco and babadotan leaves 60 g/L significantly affect the intensity of attacks M. testulalis, with values ranging from 8.71% -28.00%. This shows that botanical insecticides can reduce the intensity of attacks pest M. testulalis

Tabel 1. Intensity of attack M. testulalis (%) age 44, 51, 58, and 65 DAP (data already in transpormation by Arcsin √%).

Treatment	Intensity of attack (%)			
	44 DAP	51 DAP	58 DAP	65 DAP
N_0 = Control	16,43 bc	20,90 bc	26,86 bc	**28,00 c**
N_1 = Tobacco 20 g/L air	**10,66 a**	17,28 abc	19,68 abc	20,92 abc
N_2 = Tobacco 40 g/L air	**10,02 a**	13,22 abc	19,78 abc	18,26 a
N_3 = Tobacco 60 g/L air	**9,43 a**	**10,30 a**	**14,64 a**	**15,27 a**
N_4 = Babadotan 20 g/L air	15,97 bc	**12,28 a**	19,44 ab	22,66 bc
N_5 = Babadotan 40 g/L air	12,11 ab	**11,22 a**	**16,89 a**	19,41 abc
N_6 = Babadotan 60 g/L air	**8,71 a**	**9,14 a**	**13,53 a**	**13,83 a**
HSD 5%	4,07	8,32	9,69	9,20

Description: - The numbers followed the same letter in the same column are not significantly different according to test HSD 5%

Good weight pod and damaged weight pod

Result data different test on average weight god pod (not affected) and weight pod damaged (attacked) per plot (kg) were converted (Tonnes/Ha) during the twelve times at harvests are presented in Table 2.

Tabel 2. Weight of pods attacked and not attacked per plot (Kg), and the converted (Tonnes/ Ha) for harvest 12 times

Treatment	Average Value			
	Weight of good pods (not attacked)		Weight of damaged (attacked)	
	Per Plot (Kg)	Conversion (Ton/Ha)	Per Plot (Kg)	Conversion (Ton/ha)
N_0 = Control	4,16 a	9,46 a	2,56 b	5,82 b
N_1 = Tobacco 20 g/L air	5,29 a	12,02 a	1,83 ab	4,16 ab
N_2 = Tobacco 40 g/L air	6,08 b	13,81 b	1,44 ab	3,27 ab
N_3 = Tobacco 60 g/L air	5,91 b	13,43 b	**1,25 a**	**2,85 a**
N_4 = Babadotan 20 g/L air	5,75 ab	13,07 ab	1,20 a	2,74 a
N_5 = Babadotan 40 g/L air	7,25 bc	16,47 bc	1,11 a	2,52 a
N_6 = Babadotan 60 g/L air	**8,78 c**	**19,96 c**	**0,80 a**	**1,82 a**
HSD 5%	1,65	3,75	1,26	2,87

Description: - The numbers followed the same letter in the same column are not significantly different according to test HSD 5%

Conditions of crop yields growth ie weight of good pod (not attacked), weight of damaged pods (attacked) and the number of pods harvested fresh (good and damaged) per plot were converted (Ton/Ha) at the time of the study are presented in Figures 1, 2 and 3.

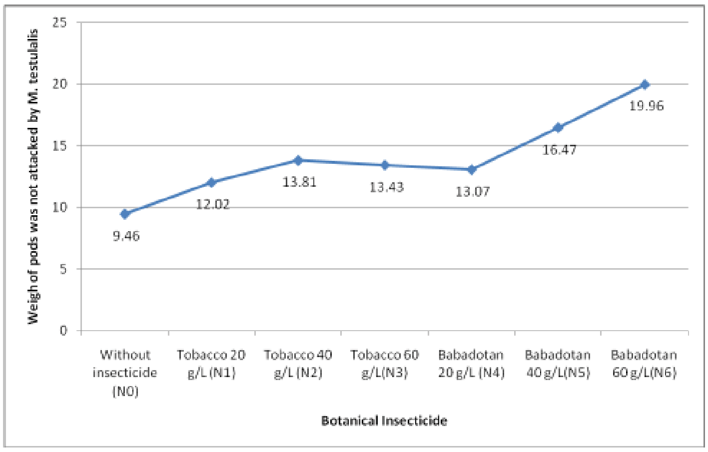

Figure 1. Weight of long bean pods that are not attacked M.testulalis per plot were converted (Ton/Ha).

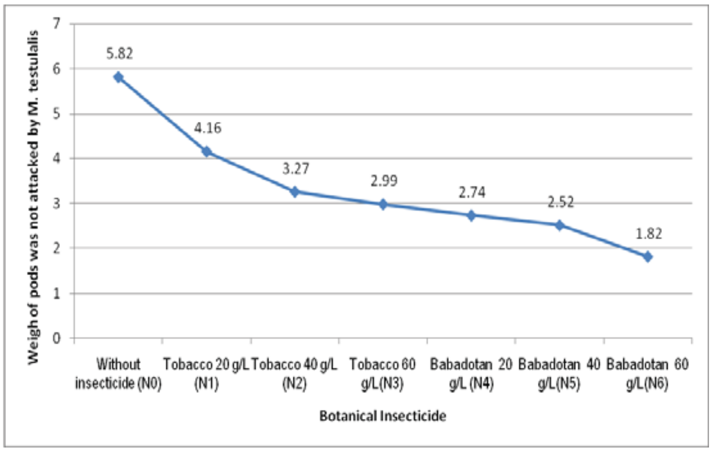

Figure 2. Weight of long bean pods that are attacked M.testulalis per plot were converted (Ton / Ha).

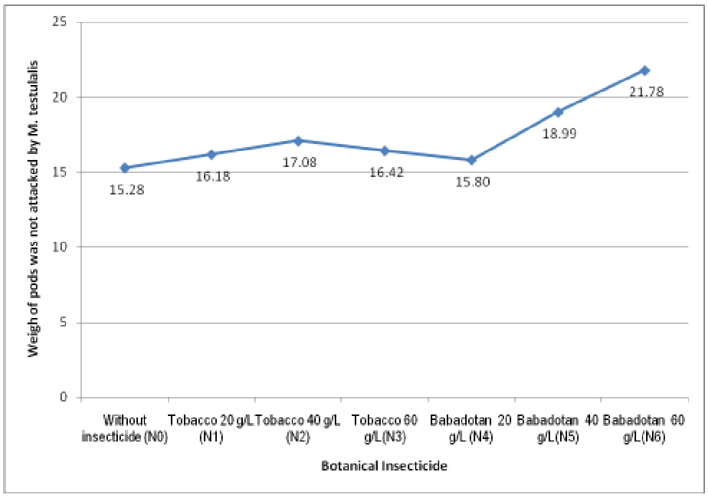

Figure 3. Harvest of fresh long beans pods (attacked and not attacked by pests M. testulalis) per plot were converted (Ton/Ha).

DISCUSSION

The ineffective tobacco extract addition is supposedly because tobacco leaf that used is dry and had a long time on the market so the nicotine is vaporized, as proposed by Oka (1993) even though nicotine is highly toxic to insects, but it evaporates quickly and easily biodegradable, so it was not long enough leave a residue on the plant.

Babadotan leaf is given to control pests M. testulalis on long beans plants showed better results than leaf tobacco at all ages observation. Suspected of the content of secondary metabolites on leaves and flowers babadotan unwelcome pests M. testulalis. Babadotan plant is also known as weeds in crops and plantations. Leaves and flowers besides contain saponins, flavonoids, and polyphenol also contain two types of active ingredients, namely precocene I (7-methoxy-2,2-dimethyl-2H-1-benzopyran) and precocene II (6,7-dimethoxy-2, 2-dimethyl-2H-1-benzopyran) (Kardinan, et al, 1999; Moenandir, 1990;).

Bioactive content saponin- flavonoids-polyphenols—volatile oil character contacts are causing delays growth of larvae into pupae (Rachmat and Wahyono, 2007). Toxic chemical compounds from procene I and II are also able to work in synthetic and contacts against pests M. testulalis. Besides, it is also an anti-hormone compounds juvenill (the hormone that is needed in the process of insect metamorphosis and reproduction repropduksi) (Darwiati and SE, Intari 2005 in Watts, JM and B. Brandwijk. 1962).

Although classified as moderate intensity of attack on control treatment, the pod borer attack may result in losses quantitatively. According Kalshoven (1981) larval M. testulalis eating young pods resulting in decaying, it makes the consumer does not want to eat the pods. Giving babadotan leaf can reduce the intensity of pest attacks M. testulalis from 7.72 to 14.17% during the four times compared to the control application. Babadotan leaves an that interferes weed plants, however for further utilization must be developed as a botanical insecticide mainly on the use of farm level.

CONCLUSIONS

From these studies it can be concluded that:

1. Application of botanical insecticides tobacco and babadotan leaves were significant effect on the intensity of attack, good pod weight (not affected) and damaged pod weight (infected), and harvest.
2 Botanical insecticides from babadotan leaf 60 g/ L effectively used in pest control bean Pod borer M. testulais compared tobacco leaf and without the application of botanical insecticides

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REFERENCES CITED

Anonim. 2013. Statistik Hortikultura Kalimantan Tengah Tahun 2013. Dinas Pertanian dan Peternakan Provinsi Kalimantan Tengah. Palangka Raya.

Darmiati, W dan S.E. Intari. 2005. Uji Toksikologi Daun Babadotan (Ageratum conyzoides

L) dan Cente Manis (Lantana camara L) terhadap Hama Penggerek Pucuk Mahoni (Lepidoptera:Pyralidae). J. Info Hutan II(4): 353-358

Direktorat Perlindungan Tanaman Hortikultura. 2007. Metode Pengamatan Organisme Pengganggu Tumbuhan (OPT) Tanaman Sayuran. Direktorat Jenderal Hortikultura. Jakarta.

Direktorat Perlindungan Tanaman Pangan. 2008. Teknologi Pengendalian Organisme Pengganggu Tumbuhan (OPT) Ramah Lingkungan. Direktorat Jenderal Tanaman Pangan. Jakarta. 85 hal.

Kalshoven. L.G.E. 1991. The Pest of Crops In Indonesia.   Revised and translated by P.A. Van Der Laan. P.T. Ichtiar Baru Van Hoeve. Jakarta.

Kardinan,A., Jasni dan M. Iskandar. 1999. Pengaruh Ekstrak daun Mimba, Sirsak dan bunga piretrum terhadap mortalitas dan serangan rayap kayu kering Criptotermes cynocephalus. Dalam Prosiding Forum Komunikasi Ilmiah Pemanfaatan Pestisida Nabati, Bogor, 9-10 Nopember 1999. 227-232.

Moenandir, J. 1990. Pengantar Ilmu dan Pengendalian Gulma. Buku I. Penerbit Rajawali Jakarta.

Nurtika, Nunung. 1993. Budidaya Tanaman Kacang Panjang. Makalah pada Pelatihan PHT Rintisan Kacang Panjang di Laboratorium Pengamatan Hama dan Penyakit Tanaman Jatisari, 29 April-5 Mei 1993. Karawang-Jawa Barat

Oka IN, 1993. Penggunaan, Permasalahan Serta Prospek Insektisida Botanik Dan Jasad Renik Dalam Pengendalian Hama Terpadu. (Makalah disajikan dalam Seminar Hasil Penelitian Dalam Rangka Pemanfaatan Insektisida Botanis). Bogor.

Palm, C.E.,W.W. Dykstra, G. Fergusson, E.Hansberry, W.Y, Hayes, J.R.L.W. Hazleton, J.C. Horsfall, E.F. Knipling, L.D. Leach, R.L. Lovvorn, and G.A. Swanson. 1970. Insect pest management and control. Principles of plant and animal pest control.

Rachmat, M., Wahyono, D., 2007. Tanaman Biofarmaka Sebagai Bioinsektisida. Direktorat Budidaya Tanaman Sayuran dan Biofarmaka. Direktorat Jenderal Hortikultura Bekerja sama dengan Balai Penelitian Tanaman Obat dan Aromatik. Jakarta.

Agroforestry pattern in peat-swam forest in Jabiren, Pulang Pisau, Central Kalimantan

Wahyudi[1)], Andy Russel Mojiol[2)] and Sona Suhartana[3)]

[1)] Department of Forestry, Faculty of Agriculture, Palangka Raya University, Palangka Raya, Indonesia. Cp. E-mail address: wahyudi888@yahoo.com
[2)] School of International Tropical Forestry, Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah Malaysia
[3)] Forest Research and Development Agency, Indonesia Ministry of Forestry, Bogor

Peat-swamp forests in Indoensia are located in few areas such as Sumatera, Kalimantan, and Papua. Many had been ruined by repeated fires and poor land use. One of the efforts to improve degraded peat-swam forest is by developing an agro forestry system. The aimed of this study were to know the pattern of agro forestry and to evaluate the growth performance of some indigenous trees combine with fruits plantation that had been planted in peat swamp forest in Jabiren Village, Pulang Pisau District, Central Kalimantan, since 2003. The treatments were consisted of land processing using drainage ditch, fertilizing, and weeding. Research result found that the pattern of agro forestry consisted of species mixture of pantung (Dyera costulata) 5.85 ha (60%), karet (Hevea brasiliensis) 0.56 ha (5.71%), fruits 2.51 ha (25.71%), vegetables 0.28 ha (2.86%), and infrastructure with 0.56 ha (5.71%). In this site, fruits comprised of cempedak (Artocarpus integer), petai (Parkia speciosa), rambutan (Nephelium lappaceum), darian (Durio zibethinus), paken (Durio kutejensis), and apokat (Persea americana), whereas vegetables consist of string bean, cassava, sweet potato, chili etc. Research result also indicated that mean annual increment (MAI) to diameter and height of pantung were 2.15 cm year^{-1} and 1.01 m year^{-1}, karet were 2.39 cm year^{-1} and 1.37 m year^{-1}, cempedak were 2.82 cm year^{-1} and 0.83 m year^{-1}, petai were 2.02 cm year^{-1} and 0.84 m year^{-1}, rambutan were 1.41 cm year^{-1} and 0.43 m year^{-1}, durian were 1.22 cm year^{-1} and 1.37 m year^{-1}, paken were 1.04 cm year^{-1} and 0.62 m year^{-1}, and apokat were 1.67 and 0.51 respectively. There was a significant difference in term of relative diameter growth rate between pantung against (higher than) some fruits plantation, however cempedak and karet were the highest and significant difference in term of relative diameter growth rate with all other at the level of $P \leq 0.05$. The findings indicates that pantung, karet, and cempedak were suitable plant species to be planted at degraded peat swamp forest in Jabiren for the purpose of reforestation using open area planting technique, while rambutan, durian, paken and apokat were not suitable due to environmental consideration. The better growth performance of pantung, karet and cempedak species are because they can easily adapted with open area planting at the study area.

Keywords: degraded peat forest, open area, reforestation

Introduction

Large of peat swam forest area in Indonesia is 17 million ha or a half of world tropical peat swam forest (Bellamy, 1997). Peat-swam forest area in Indoensia is located in Sumatera (9.7 million ha), Kalimantan (6.3 million ha), and Papua (0,7 million ha) (Daryono, 2000), but a large amount has been ruined by repeated fires and poor land use. Forest degradation is often correlated with the critical land, especially in tropical developing countries. There are some causes of forest degradation i.e illegal logging, illegal occupation of forest land, forest conversion, poorly managed forest concession, excessive timber demand, forest fire, and population explosion (Wahyudi, 2012). According to Indonesia Ministry of Forestry Regulation No.10.1/Kpts-II/2000 and Indonesia Government Regulation No.34/2002, Plantataion Forest Project is just directed to degraded forest area only such as shrubs (bushes and underbrush), grassland, and other critical land including low potential forest.

Acoording the G-20 Leaders Summit in Pittsburgh on 25 September 2009, Indonesia has been committed to cut its greenhouse gas emissions by 26% to 2020. Reducing emissions will be achieved largely by devising policies targeting the land-use, land-use change, and Forestry sector. Peat and their sectors related emissions are by far the largest contributors to Indonesia's current and expected future emissions, and represent the largest opportunities to abate emissions (DNPI, 2011). Several challenges persist in interpreting the emission reduction policy due to the varying estimates of GHG emissions from peat drainage and fires. While a great deal of research on peat emissions and measurement is ongoing in Indonesia, the scientific understanding of peat-related emissions is still developing, especially for those in tropical regions. Therefore, it is imperative that a comprehensive and robust framework is devised to resolve critical issues pertaining to peat land management and associated greenhouse gas emissions (DNPI, 2012).

In Central Kalimantan, peat swam forest area are locate in District of Kapuas, Pulang Pisau, Palangka Raya, and South Barito (Mulyanto, 2000). One of some efforts to improve degraded peat-swam forest is by developing an agroforestry system. This system also could to prevent forest fire because the peoples actively keep their land. One of agroforestry systems that conducted in peat forest is contained in Jabiren Village, Pulang Pisau District, Central Kalimantan. It has been developed since 2003 to present using some trees, i.e. pantung (Dyera costulata), karet (Hevea brasiliensis), and fruits i.e. cempedak (Artocarpus integer), Petai (Parkia speciosa), rambutan (Nephelium lappaceum), durian (Durio zibethinus), paken (Durio kutejensis), and apokat (Persea americana).

Scientific Peatland Definitions

Peat as a plant residue formed naturally through long-term decomposition processes, accumulating in swamp areas or static reservoirs (Ministry of Environment of Indonesia). According to the Ministry of Agriculture of Indonesia, peat as soil formed as a result of organic matter accumulation with a naturally occurring composition of greater than 65% from the decaying vegetation growing on it, whose decomposition is slowed down by anaerobic and wet conditions. Meanwhile, the Ministry of Forestry of Indonesia defines peat as organic matter residue accumulating over a long period of time. These definitions are based on field observations and analyses of peat soil properties. Key elements include physical peat properties, such as degree of decomposition (humification), bulk density, water content, porosity and others, and chemical properties, such as carbon content, ash content, pH, and C/N ratio (DNPI, 2012).

Defining peatland and proposed follow up activities as follow:

a. A comprehensive peatland definition has to cover the key elements of carbon content or mineral content and minimum depth.
b. Peatland is an area with an accumulation of partly decomposed organic matter, with ash content equal to or less than 35%, peat depth equal to or deeper than 50 cm, and organic carbon content (by weight) of at least 12%.
c. Four categories for peatland delineation are recommended based on the following classification: (1) Peat depth, (2) Peat layer, (3) Hydrological area in peatland, and (4)

Aimed of Research

The aimed of this study were to know the pattern of agroforestry and to evaluate the growth performance of some indigenous trees combine with fruits plantation that had been planted in peat swamp forest in Jabiren Village, Pulang Pisau District, Central Kalimantan, since 2003. The research result is expected to provide correct information about agroforestry system in the peat forest to stakeholder, especially the community in the surrounding peat forest areas and could create optimistic attitude for all entrepreneurs to develop degraded peat forest area using agroforestry system in the site.

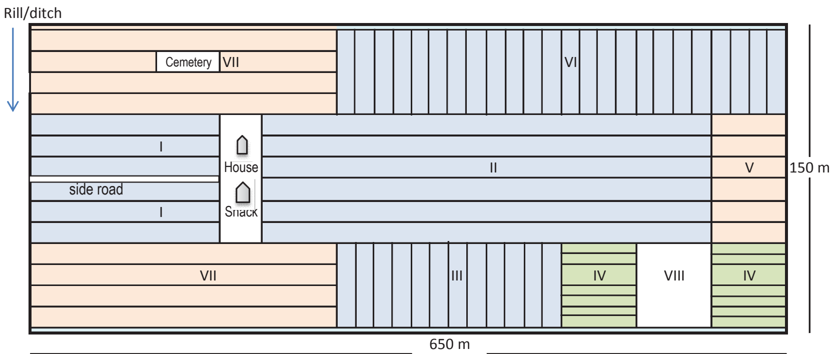
Methods

The research had been conducted at plots of peat swamp forest with agroforestry system, in Jabiren Village, Pulang Pisau District, Central Kalimantan, since 2003. Climate type of A (Schmidt and Ferguson, 1951) with initially condition of sites were scrubs in the degraded peat-swam forest that dominated by vegetations of Melaleuca leucadendron, Nephrolepis biserrata, Dicranopteris linearis, etc. The treatments were consisted of land processing using drainage ditch, fertilizing, and weeding. The anorganic manure of urea was used of 1 kg per three at the first three years.

Research Stages were 1) measuring the wide (length and width) of agroforestry site in the peat-forest, 2) mapping research plot design, 3) recording the age, wide, number, diameter, height, and their treatments history of each plant that planted/contained in the research plot, i.e. pantung (Dyera costulata), karet (Hevea brasiliensis), cempedak (Artocarpus integer), petai (Parkia speciosa), rambutan (Nephelium lappaceum), durian (Durio zibethinus), paken (Durio kutejensis), and apokat (Persea americana), and 4) collecting the diameter and height of eight trees and fruits that be planted in the site to determine their mean annual increment (MAI). Data were analyzed using homogeneity test, analyze of varians (ANOVA), and Least Significant Different (LSD) test using SPSS 19.0.

Result and Discussion

Some indigenous tress and fruits that planted/contained in the research plot were pantung (Dyera costulata), karet (Hevea brasiliensis), cempedak (Artocarpus integer), petai (Parkia speciosa), rambutan (Nephelium lappaceum), darian (Durio zibethinus), paken (Durio kutejensis), and apokat (Persea americana), whereas vegetables consist of string bean (Vigna unguiculata), cassava (Manihot esculenta), sweet potato (Ipomoea batatas), yam (Dioscorea spp), chili etc. Layout of trees and fruits in the research plot could be seen at Fig.1.



Explanation:

Plants & others	Large (m2)	Large (ha)	Procentace (%)
I. Pantung	8.357	0,84	8,57
II. Pantung	25.071	2,51	25,71
III. Pantung	8.357	0,84	8,57
IV. Karet	5.571	0,56	5,71
V. Fruits	4.179	0,42	4,29
VI. Pantung	16.714	1,67	17,14
VII. Fruits	20.893	2,09	21,43
VIII.Vegetables	2.786	0,28	2,86
Infrastructure	4.179	0,42	4,29
Family grave	1.393	0,14	1,43
Total	97.500	9,75	100,00

Fig. 1. Agroforestry pattern in the research plot

Research result found that the pattern of agroforestry consisted of species mixture of pantung (Dyera costulata) 5.85 ha (60%), karet (Hevea brasiliensis) 0.56 ha (5.71%), fruits 2.51 ha (25.71%), vegetables 0.28 ha (2.86%), and infrastructure with 0.56 ha (5.71%). In this site, fruits comprised of cempedak (Artocarpus integer), petai (Parkia speciosa), rambutan (Nephelium lappaceum), darian (Durio zibethinus), paken (Durio kutejensis), and apokat (Persea americana), whereas vegetables consist of string bean, cassava, sweet potato, chili etc.

For the survivality results, they shows that the species of pantung, karet, petai, cempedak, paken, durian, rambutan, apokat species have survivality rate at 83.5%, 80.8%, 70.1%, 61,6%, 45%, 43%, 39%, and 31% respectively.

The average diameters of some indigenous trees and fruits that be planted in the peat-swam forest areas in the form of mean annual increment (MAI) were showed at the Table 1, meanwhile the height data of them were showed at the Table 2.

Table 1. The mean annual increment of diameter of eight trees and fruits planted in the peat-swam forest

No	Pantung (cm)	Karet (cm)	Cempedak (cm)	Petai (cm)	Rambutan (cm)	Durian (cm)	Paken (cm)	Apokat (cm)
1	1,6	1,9	3,1	2,2	1,9	1,22	1,04	1,5
2	2,6	2,7	2,9	2,9	1,8	1	1,4	1,9
3	2,1	2,1	2,8	2	1	1,3	0,88	1,6
4	2,3	2,72	2,7	1,9	1,3	1,7	1	1,45
5	2,15	2,51	2,6	1,1	1	0,9	0,9	1,9
Σ	2,15	2,39	2,82	2,02	1,40	1,22	1,04	1,67

Source: Worked data

Research result also indicated that mean annual increment (MAI) to diameter and height of pantung were 2.15 cm year^{-1} and 1.01 m year^{-1}, karet were 2.39 cm year^{-1} and 1.37 m year^{-1}, cempedak were 2.82 cm year^{-1} and 0.83 m year^{-1}, petai were 2.02 cm year^{-1} and 0.84 m year^{-1}, rambutan were 1.41 cm year^{-1} and 0.43 m year^{-1}, durian were 1.22 cm year^{-1} and 1.37 m year^{-1}, paken were 1.04 cm year^{-1} and 0.62 m year^{-1}, and apokat were 1.67 and 0.51 respectively (Table 1 and 2).

Table 2. The mean annual increment of height of eight trees and fruits planted in the peat-swam forest

No	Pantung (m)	Karet (m)	Cempedak (m)	Petai (m)	Rambutan (m)	Durian (m)	Paken (m)	Apokat (m)
1	1	1,5	0,5	0,84	0,33	1,4	0,4	0,6
2	1,3	1,2	0,9	0,68	0,6	1,25	0,7	0,4
3	0,9	1,1	1,12	0,9	0,5	1,34	0,5	0,54
4	0,85	1,88	0,67	0,89	0,4	1,37	0,6	0,4
5	1	1,19	0,97	0,9	0,32	1,5	0,9	0,61
Σ	1,01	1,37	0,83	0,84	0,43	1,37	0,62	0,51

Source: Worked data

According to the homogeneity test, the data of diameter and height of eight trees were the significant value each equal to 0.017 and 0.014 which was smaller than 0.05 so that all data were homogeneous. Analysis of variation of diameter and height growth of eight trees and fruits showed by significant value < 0.05 (SPSS 19.0), they were indicating that there were significant different between one or more the treatments at 0.05 level (Table 3a and 3b).

Table 3. Anova of diameter (a) and height (b) growth of eight trees at 0,05 level

Varians	Sum of Squares	df	Mean Square	F	Sig.
Between groups	13.113	7	1.873	13.682	0.000
Within groups	4.381	32	0.137		
Total	17.494	39			

b

Varians	Sum of Squares	df	Mean Square	F	Sig.
Between groups	4.567	7	0.652	19.110	0.000
Within groups	1.093	32	0.034		
Total	5.660	39			

Source: Worked data

Diameter Growth Analysis

According to the Least Significant Different (LSD) test could be explained the diameter growth levels of one plant against the other plants. First, pantung (Dyera costulata) was not significant difference in term of relative diameter growth rate between karet and petai with value of sig. were 0.321 and 0.582 respectively (>0.05), so these three trees were significant different (higher) against the others trees and fruits (cempedak, rambutan, durian, paken, and apokat).

Second, karet (Hevea brasiliensis) was not significant difference in term of relative diameter growth rate between pantung, cempedak dan petai, with value of sig. were 0.321, 0.073, and 0.128 respectively (>0.05) and significant different (higher) against the other trees and fruits.

Third, cempedak (Artocarpus integer) was not significant difference in term of relative diameter growth rate between karet with value of sig. was 0.073 (>0.05) but significant different (lower) against pantung and petai, conversely it was significant different (higher) against to the other trees and fruits.

Fourth, petai (Parkia speciosa) was not significant difference in term of relative diameter growth rate between pantung, karet, and apokat with value of sig. were 0.582, 0.128, and 0.145 respectively (>0.05) but significant different (higher) against to the other trees and fruits.

Fifth, rambutan (Nephelium lappaceum) was not significant difference in term of relative diameter growth rate between durian, paken, and apokat with value of sig. were 0.458, 0.138, and 0.257 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

Sixth, durian (Durio zibethinus) was not significant difference in term of relative diameter growth rate between rambutan, paken, and apokat with value of sig. were 0.458, 0.447, and 0.066 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

Then, paken (Durio kutejensis) was not significant difference in term of relative diameter growth rate between rambutan and durian with value of sig. were 0.138, and 0.447 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

Finally, apokat (Persea americana) was not significant difference in term of relative diameter growth rate between petai, rambutan, and durian with value of sig. were 0.145, 0.257, and 0.066 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

Height Growth Analysis

According to the Least Significant Different (LSD) test could be explained the height growth levels of one plant against the other plants. First, pantung (Dyera costulata) was not significant difference in term of relative height growth rate between cempedak and petai with value of sig. were 0.138 and 0.16 respectively (>0.05), and significant different (lower) than karet and durian, however higher than the others trees and fruits.

Second, karet (Hevea brasiliensis) was not significant difference in term of relative height growth rate between durian with value of sig. was 0.986 (>0.05) and significant different (higher) against the other trees and fruits.

Third, cempedak (Artocarpus integer) was not significant difference in term of relative height growth rate between pantung, petai,and paken with value of sig. were 0.138, 0.932, and 0.079 (>0.05) but significant different (lower) against karet and durian, conversely it was significant different (higher) against to the other trees and fruits (rambutan and apokat).

Fourth, petai (Parkia speciosa) was not significant difference in term of relative height growth rate between pantung, cempedak, and paken with value of sig. were 0.160, 0.932, and 0.067 (>0.05) but significant different (lower) against karet and durian, conversely it was significant different (higher) against to the other trees and fruits (rambutan and apokat).

Fifth, rambutan (Nephelium lappaceum) was not significant difference in term of relative height growth rate between paken and apokat with value of sig. were 0.114, 0.499 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

Sixth, durian (Durio zibethinus) was not significant difference in term of relative height growth rate between karet with value of sig. was 0.986 (>0.05) but significant different (higher) against to the other trees and fruits.

Then, paken (Durio kutejensis) was not significant difference in term of relative height growth rate between cempedak, petai, rambutan,and apokat with value of sig. were 0.079, 0.67, 0.114, and 0.354 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

Latest, apokat (Persea americana) was not significant difference in term of relative height growth rate between rambutan and paken with value of sig. were 0.449, 0.354 respectively (>0.05) but significant different (lower) against to the other trees and fruits.

The findings indicates that pantung, karet, and cempedak were very suitable plants species to be planted at degraded peat swamp forest in Jabiren for the purpose of reforestation using open area planting technique, while rambutan, durian, paken and apokat were not suitable due to environmental consideration. The better growth performance of pantung, karet and cempedak species are because they can easily adapted with open area planting at the study area.

Conclusion

Agroforestry pattern in Jabiren Raya is mixed plantation between some trees, fruits, and vegetables, they contained pantung (Dyera costulata), karet (Hevea brasiliensis), cempedak (Artocarpus integer), petai (Parkia speciosa), rambutan (Nephelium lappaceum), darian (Durio zibethinus), paken (Durio kutejensis), and apokat (Persea americana), whereas vegetables consist of string bean (Vigna unguiculata), cassava (Manihot esculenta), sweet potato (Ipomoea batatas), yam (Dioscorea spp), chili etc.

Pantung, karet, and cempedak are very suitable plants species to be planted at degraded peat swamp forest in Jabiren for the purpose of reforestation using open area planting technique because they can easily adapted with open area planting at the site. The survivality of three plants are 83.5%, 80.8%, and 61,6% respectively. MAI of diameter and height of pantung are 2.15 cm year^{-1} and 1.01 m year^{-1}, karet are 2.39 cm year^{-1} and 1.37 m year^{-1}, and cempedak are 2.82 cm year^{-1} and 0.83 m year^{-1} respectively.

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Reference

Barnett, J.R. and G. Jeronimidi. 2003. Wood Quality and Its Biological Basis. Blackwell Publishing CRC Press.

Bellamy, D.J., 1997. Peatland of Indonesia: Their key role in global conservation-can they be used sustainably. In: Rieley, I.O. and S.E. Tropical Peatland Samara Pub. Cardigan. P:19-21.

Daryono, H., 2000. Kondisi hutan setelah penebangan dan pemilihan pohon yang sesuai untuk rehabilitasi dan pengembangan hutan tanaman di lahan rawa gambut. Prosiding Seminar Pengelolaan Hutan Rawa Gambut, Balai Teknologi Reboisasi Banjarbari. P:21-43.

De Foresta, H., A. Kusworo, G. Michon, W.A. Djatmiko. 2000. Agroforestry in Indonesia. ICRAF Southeast Asia. SMT Grafika Desa Putera, Jakarta.

DNPI, 2012. Policy Memo: Peatland Definition from Uncertainty to Certainty.

Fisher, R.F., Dan Binkley. 2000. Ecology and Management of Forest Soil. Third Edition. John Wiley & Sons, Inc., New York.

Gardner, F.P., R. Brent P., Roger L.M. 1991. Physiology of Crop Plant. The Iowa State University Press.

Giesen, W. 1991. Berbak Wildlife Reserve, Jambi. Reconnaisance Survey Report. PHPA/AWB Sumatera Wetland Project Report No.13. Asean Wetland Bureau-Indonesia. Bogor

Haygreen, J.G., and L.B. Jim. 1982. Forest Product and Wood Science. The Iowa State University Press.

Kosasih, A.S., Rina B., Budi R. 2006. The Silviculture of Mixed Forest Plantation. Forda, Ministry of Forestry, Republic of Indonesia, Bogor.

Kozlowski TT, Pallardy SG. 1997. Physiology of Woody Plants. Academic Press.

Lahjie, A.M. 2004. The Agroforestry Technique. University of Mulawarman, Samarinda.

Manan, S. 1995. Why Using Mixed Forest Plantation? Paper on Landscaping Seminar. General Director of Forest Utility, Ministry of Forestry, Republic of Indonesia, Jakarta

McKinnon, K., G.Hatta, Hakimah H., Arthur M. 2000. Ecologi of Kalimantan. Canadian International Development Agency. Prenhallindo, Jakarta.

Ministry of Agriculture, 2003. Technical Guideline of Land Evaluation for Agricultural Commodity. Agricultural Research and Development Agency, Ministry of Agriculture, Republic of Indonesia, Bogor.
Ministry of Forestry, 1996. Explanation of Participatory Rural Appraisal (PRA). Ministry of Forestry, Republic of Indonesia, Jakarta.
Ministry of Forestry, 2007. Community Plantation Forest Development. Background, Fact, and Policy. Ministry of Forestry, Republic of Indonesia, Jakarta.
Sabarnurdin, S. 2008. Agroforestry. Strategy for Land Utility to Sustainability Development. Faculty of Forestry, Gadjah Mada University, Yogyakarta.
Sutedjo, M.M., A.G. Kartasapoetra. 1991. Introduction of Soil Science. Penerbit Rineka Cipta, Jakarta.
Suratmo, F.G., E.A. Husaeni, N. Surati J. 2003. Basic Science of Forest Fire. Fakulty of Forestry, Bogor Agricultural University, Bogor.
Suyatno. 2004. Forest Fire, Problems and Its Solution. Center for International Forest Research (CIFOR), Bogor.
Wibowo, A. 2003. Forest Fire Prevention in Indonesia. Forest Research and Development Agency, Bogor.
Wahyudi. 2012. Indonesian Tropical Forest, Biodiversity Conservation and Ecotourism Development. In the Proceeding of the International German Alumni Summer School of Biodiversity Management and Tourism Development. Cuvillier Verlag Goettingen, Germany.

Enclosure

Least significant different (LSD) test for diameters (left) and heights (right) of eight trees and fruits

Multiple Comparisons

VAR00002
LSD

(I) VAR00001	(J) VAR00001	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-.23600	.23402	.321	-.7127	.2407
	3	-.67000*	.23402	.007	-1.1467	-.1933
	4	.13000	.23402	.582	-.3467	.6067
	5	.75000*	.23402	.003	.2733	1.2267
	6	.92600*	.23402	.000	.4493	1.4027
	7	1.10600*	.23402	.000	.6293	1.5827
	8	.48000*	.23402	.049	.0033	.9567
2	1	.23600	.23402	.321	-.2407	.7127
	3	-.43400	.23402	.073	-.9107	.0427
	4	.36600	.23402	.128	-.1107	.8427
	5	.98600*	.23402	.000	.5093	1.4627
	6	1.16200*	.23402	.000	.6853	1.6387
	7	1.34200*	.23402	.000	.8653	1.8187
	8	.71600*	.23402	.004	.2393	1.1927
3	1	.67000*	.23402	.007	.1933	1.1467
	2	.43400	.23402	.073	-.0427	.9107
	4	.80000*	.23402	.002	.3233	1.2767
	5	1.42000*	.23402	.000	.9433	1.8967
	6	1.59600*	.23402	.000	1.1193	2.0727
	7	1.77600*	.23402	.000	1.2993	2.2527
	8	1.15000*	.23402	.000	.6733	1.6267
4	1	-.13000	.23402	.582	-.6067	.3467
	2	-.36600	.23402	.128	-.8427	.1107
	3	-.80000*	.23402	.002	-1.2767	-.3233
	5	.62000*	.23402	.012	.1433	1.0967
	6	.79600*	.23402	.002	.3193	1.2727
	7	.97600*	.23402	.000	.4993	1.4527
	8	.35000	.23402	.145	-.1267	.8267
5	1	-.75000*	.23402	.003	-1.2267	-.2733
	2	-.98600*	.23402	.000	-1.4627	-.5093
	3	-1.42000*	.23402	.000	-1.8967	-.9433
	4	-.62000*	.23402	.012	-1.0967	-.1433
	6	.17600	.23402	.458	-.3007	.6527
	7	.35600	.23402	.138	-.1207	.8327
	8	-.27000	.23402	.257	-.7467	.2067
6	1	-.92600*	.23402	.000	-1.4027	-.4493
	2	-1.16200*	.23402	.000	-1.6387	-.6853
	3	-1.59600*	.23402	.000	-2.0727	-1.1193
	4	-.79600*	.23402	.002	-1.2727	-.3193
	5	-.17600	.23402	.458	-.6527	.3007
	7	.18000	.23402	.447	-.2967	.6567
	8	-.44600	.23402	.066	-.9227	.0307
7	1	-1.10600*	.23402	.000	-1.5827	-.6293
	2	-1.34200*	.23402	.000	-1.8187	-.8653
	3	-1.77600*	.23402	.000	-2.2527	-1.2993
	4	-.97600*	.23402	.000	-1.4527	-.4993
	5	-.35600	.23402	.138	-.8327	.1207
	6	-.18000	.23402	.447	-.6567	.2967
	8	-.62600*	.23402	.012	-1.1027	-.1493
8	1	-.48000*	.23402	.049	-.9567	-.0033
	2	-.71600*	.23402	.004	-1.1927	-.2393
	3	-1.15000*	.23402	.000	-1.6267	-.6733
	4	-.35000	.23402	.145	-.8267	.1267
	5	.27000	.23402	.257	-.2067	.7467
	6	.44600	.23402	.066	-.0307	.9227
	7	.62600*	.23402	.012	.1493	1.1027

*. The mean difference is significant at the 0.05 level.

Multiple Comparisons

VAR00004
LSD

(I) VAR00003	(J) VAR00003	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	2	-.36400*	.11686	.004	-.6020	-.1260
	3	.17800	.11686	.138	-.0600	.4160
	4	.16800	.11686	.160	-.0700	.4060
	5	.58000*	.11686	.000	.3420	.8180
	6	-.36200*	.11686	.004	-.6000	-.1240
	7	.39000*	.11686	.002	.1520	.6280
	8	.50000*	.11686	.000	.2620	.7380
2	1	.36400*	.11686	.004	.1260	.6020
	3	.54200*	.11686	.000	.3040	.7800
	4	.53200*	.11686	.000	.2940	.7700
	5	.94400*	.11686	.000	.7060	1.1820
	6	.00200	.11686	.986	-.2360	.2400
	7	.75400*	.11686	.000	.5160	.9920
	8	.86400*	.11686	.000	.6260	1.1020
3	1	-.17800	.11686	.138	-.4160	.0600
	2	-.54200*	.11686	.000	-.7800	-.3040
	4	-.01000	.11686	.932	-.2480	.2280
	5	.40200*	.11686	.002	.1640	.6400
	6	-.54000*	.11686	.000	-.7780	-.3020
	7	.21200	.11686	.079	-.0260	.4500
	8	.32200*	.11686	.010	.0840	.5600
4	1	-.16800	.11686	.160	-.4060	.0700
	2	-.53200*	.11686	.000	-.7700	-.2940
	3	.01000	.11686	.932	-.2280	.2480
	5	.41200*	.11686	.001	.1740	.6500
	6	-.53000*	.11686	.000	-.7680	-.2920
	7	.22200	.11686	.067	-.0160	.4600
	8	.33200*	.11686	.008	.0940	.5700
5	1	-.58000*	.11686	.000	-.8180	-.3420
	2	-.94400*	.11686	.000	-1.1820	-.7060
	3	-.40200*	.11686	.002	-.6400	-.1640
	4	-.41200*	.11686	.001	-.6500	-.1740
	6	-.94200*	.11686	.000	-1.1800	-.7040
	7	-.19000	.11686	.114	-.4280	.0480
	8	-.08000	.11686	.499	-.3180	.1580
6	1	.36200*	.11686	.004	.1240	.6000
	2	-.00200	.11686	.986	-.2400	.2360
	3	.54000*	.11686	.000	.3020	.7780
	4	.53000*	.11686	.000	.2920	.7680
	5	.94200*	.11686	.000	.7040	1.1800
	7	.75200*	.11686	.000	.5140	.9900
	8	.86200*	.11686	.000	.6240	1.1000
7	1	-.39000*	.11686	.002	-.6280	-.1520
	2	-.75400*	.11686	.000	-.9920	-.5160
	3	-.21200	.11686	.079	-.4500	.0260
	4	-.22200	.11686	.067	-.4600	.0160
	5	.19000	.11686	.114	-.0480	.4280
	6	-.75200*	.11686	.000	-.9900	-.5140
	8	.11000	.11686	.354	-.1280	.3480
8	1	-.50000*	.11686	.000	-.7380	-.2620
	2	-.86400*	.11686	.000	-1.1020	-.6260
	3	-.32200*	.11686	.010	-.5600	-.0840
	4	-.33200*	.11686	.008	-.5700	-.0940
	5	.08000	.11686	.499	-.1580	.3180
	6	-.86200*	.11686	.000	-1.1000	-.6240
	7	-.11000	.11686	.354	-.3480	.1280

*. The mean difference is significant at the 0.05 level.

Explanation:

Varians are 1) pantung (*Dyera costulata)*, 2) karet (*Hevea brasiliensis)*, 3) cempedak (*Artocarpus integer)*, 4) Petai (*Parkia speciosa),* 5) rambutan (*Nephelium lappaceum)*, 6) durian (*Durio zibethinus)*, 7) paken (*Durio kutejensis)*, and 8) apokat (*Persea americana).*

Ethnic plant resources in Central Kalimantan

Penyang Sandan[1)], Sampang Gaman[1)], Yuda Prawira[1)], and Yutaka Tamai[2)]

[1)] Department of Forestry, University of Palangka Raya, Jl Yos Sudarso, Palangka Raya 73112, INDONESIA: penyang.d.sandan@facebook.com, sampang.gaman@facebook.com, yuda.prawira.75@facebook.com
[2)] Department of Forest Science, Hokkaido University, N9W9, Kita-ku, Sapporo 060-8589, JAPAN: ytamai@for.agr.hokudai.ac.jp

Ethnic plant resource diversity and their forms of use were studied in the community of Central Kalimantan. A total of 66 species representing 41 families of ethnic plants (including mushrooms) were recorded. Relatively much number of plant species was appeared in Moraceae and Zingiberaceae. The habits were categorized as follows; Tree (27), Shrub (8), Palm (1), Bamboo (1), Rattan (3), Liana (1), Vine (4), Grass (13), Epiphyte (2) and Fern (3). Usages of the plant resources were categorized as follows; Food (vegetable, fruit, mushroom, spice, additive, etc.), Medicine, Material (craft, wood) and others (poison, repellent, charcoal, ornament etc.). Ten species belonged into two categories.

Keywords: ethnic plant, food, medicine, Palangkaraya, peat swamp forest

Introduction

The Central Kalimantan (Kalimantan Tengah: Kalteng) is one of five provinces in the Indonesian part of Borneo island. The Dayak who live there belong to the most traditional of the island. The officially recognized Kaharingan-religion, in which dozens of religious themes are kept, spread to other provinces from Kalteng. The Kalteng has about 1.5 million inhabitants and concludes about 153,800 km2 of peat swamp and jungle. The province is bordered by the river basins of the Katingan, Kahayan, Kapuas and Barito. Local districts are located around the rivers and reach from the coastal areas (lowlands) until the headwaters (highlands). The vast and sparse populated northern part of the province is made up from two districts. The coastal area around the estuaries is also sparse populated and consists of peat swamps, which reach up to 100 km inland.

Vast tropical forests that had been reported only produce large quantities of wood, actually also has many other potential, which is as a producer of non-timber forest products. There are many non-timber forest products owned, but who want to explored in this study are plant species that have traditionally been used by the people of Central Kalimantan.

Methods

*Study site.*The study site was around Palangkaraya city, Central Kalimantan.

Data collection. Data were collected through interviews of some people who were randomly selected. Background of the respondents varied, such as housewives, greengrocer, traditional medicine merchants, students, and elderly people. Besides the efforts made to collect data from a variety of literature in the library.

Data classified. The data were classified based on the habits of ethnic plants and the usages.

Results and discussion

Ethnic plant resource diversity and their forms of use were studied in the community of Central Kalimantan. A total of 69 species representing 44 families of ethnic plants (including 5 mushrooms) were recorded. Relatively much number of plant species was appeared in Moraceae (5) and Zingiberaceae (4). The habits were categorized as follows; Tree (27), Shrub (8), Palm (1), Bamboo (1), Rattan (3), Vine (4), Liana (1), Grass (13) Epiphyte (2) and Fern (3).

Usages of the plant resources were categorized as follows; Food (37 species: vegetable, fruit, mushroom, spice, additive, etc.), Medicine (29 species), Material (5 species: craft, wood) and Others (8 species: poison, repellant, charcoal, ornament etc.). Eleven species belonged into two categories.

Food

Thirty seven species belonging to 33 families were recorded as food resources. Most of them are wild, not be cultivated. Edible parts of the plants are fruits, seeds, leaves, stems, tubers and roots. Suna (Allium chinense : leaf, bulb), Rotan Irit (Calamus trachycoleus : shoot), Kalakai (Stenochlaena palustris : leaf, stem), Baluh (Cucurbita moschata : fruit), Uwi (Dioscorea alata : tuber), Bajei (Diplazium esculentum : leaf), Bakung (Hanguana malayana : inside of stem), Betung (Dendrocalamus asper : shoot), Taya (Nauclea orientalis : leaf), Rimbang (Solanum ferox : fruit), Sanggu (Solanum torvum : fruit), Potok (Etlingera hemisphaerica : stem, bulb) were used as vegetables for daily meal.
Fruits of Kasturi (Mangifera casturi : mango), Rotan Manau (Calamus manan : rattan), Paken (Durio kutejensis : durian), Manggis (Garcinia mangostana : mangosteen), Kapul (Baccaurea lanceolata), Pilang and Mangkahai (Artocarpus spp. : jackfruits), Tangkuhis (Dimocarpus malesianus : longan) , Katiau and Tanggaring (Nephelium spp. : rambutan) are also edible.
Lemba (Curculigo villosa : leaf), Kayu Manis (Cinnamomum burmannii : bark), Sasungkai (Albertisia papuana : leaf), Sarai (Cymbopogon citratus : stem, leaf), Langkuas (Alpinia galanga : rhizome), Henda (Curcuma longa : flower), Lai (Zingiber officinale : rhizome) are used as spice.
Saluang Belum (Lavanga sarmentosa : root, xylem) and Pasak Bumi (Eurycoma longifolia : root) are used not only for tonic but also medicine. Latex from Jelutung (Dyera lowii) is a substitute of chicle (chewing gum base). Edible mushrooms, Kulat Bitak (Auricularia sp. : tree ear), Kulat Siau (Hygrocybe conica : conical wax cap), Kulat Bantilung (Termitomyces spp. : termite mushroom) and Kulat Karitip (Shizophyllum commune : common split gill) were usually collected from forest, recently ear mushroom is mainly cultivated in the village.

Medicine

A total of 29 plant species belonging to 19 families were recorded as medicinal resources. Most of them were used as traditional folk medicine to treat various kinds of ailments of humans such as headache, stomachache, wounds, fever, cough, viral disease, etc.

Extractives from the bark of Sintuk (Cinnamomum sintok) is believed to have anti-malaria activity. Mixed extractives from Akar Kuning (Fibraerea chloroleuca : root) and Kulat Merah (Pycnoporus coccineus : hole) are also used as malaria cure. Root of Pasak bumi (Eurycoma longifolia) contains an analeptic stimulant, the products are still popular folk medicine. Sarang Semut (Myrmecodia pendans: tuber) is an epiphytic myrmecophyte (ant plant), used as all kinds of disease treatment. Rhizome of

Sawangkak (Costus speciosus) has been used to treat fever, rash, asthma, bronchitis and intestinal worms.

Material

Calamus spp. are well known as rattan. Rattan is used usually craft, but is also used occasionally strutual material. Since fruit of Rotan Manau (C. manan) and young shoot of Rotan Taman (C. caesius) are edible, both species are also categorized into Food.

The stems of Purun (Eleocharis dulcis) may be used for mulch, fodder, fruit and vegetable packaging, and crafts. Melaleuca leucadendra is well known as ‘Galam’, traditionally used as construction wood and carbon material.

Others

Sap from Tuwe (Mangifera foetida : horse mango) is highly toxic and used for traditional poison fishing. Ipu (Antiaris toxicaria) is a fast growing tree and source of lightweight wood. Because of the latex containing intense toxin, the tree is notorious as a poison for arrows and blow darts.

Gemor tree (Alseodaphne coriacea) bark contains insect repellant and is still commonly used for the production of mosquito coils. Katupat Napu (Nepenthes spp. : Pitcher plant) and Anggrek Tebu (Grammatophyllum speciosum : epiphytic orchid) were collected from forest and propagated in the village, then sold in the market as ornament plants.

References

Borneo Research Council (1998) Borneo Research Council Monograph Series Vol.3: Klokke AH (ed) Traditional Medicine Among The Ngaju Dayak In Central Kalimantan, Borneo Research Council Inc.

Irawan D, Wijaya CH, Limin SH, Hashidoko Y, Osaki M, Kulu IP (2006) Ethnobotanical study and nutrient potency of local traditional vegetables in Central Kalimantan. TROPICS Vol.15 (4): 441-448

Setyowati FM, Riswan S, Susiarti S (2005) Etnobotani Masyarakat Dayak Ngaju Di Daerah Timpah Kalimantan Tengah. J. Tek. Ling. P3TL-BPPT. Vol.6 (3): 502-510

Simbolon H, Mirmanto E (2000) Checklist od Plant Species in the Peat Swamp Forest of Central Kalimantan, Indonesia. Proc. Int. Natl. Symp. TROPICAL PEATLANDS, Bogor, Indonesia, Nov. 1999: 179-190

Whitmore TC, Tantra IGM, Sutisna U. Sidiyasa K, (1990) Tree flora of Indonesia: check list for Kalimantan, Ministry of Forestry, Agency for Forestry Research and Development, FORDA, Bogor

Table Ethnic plant species in Central Kalimatan. Category: F-Food, Me-Medicine, M-Material, O-Others

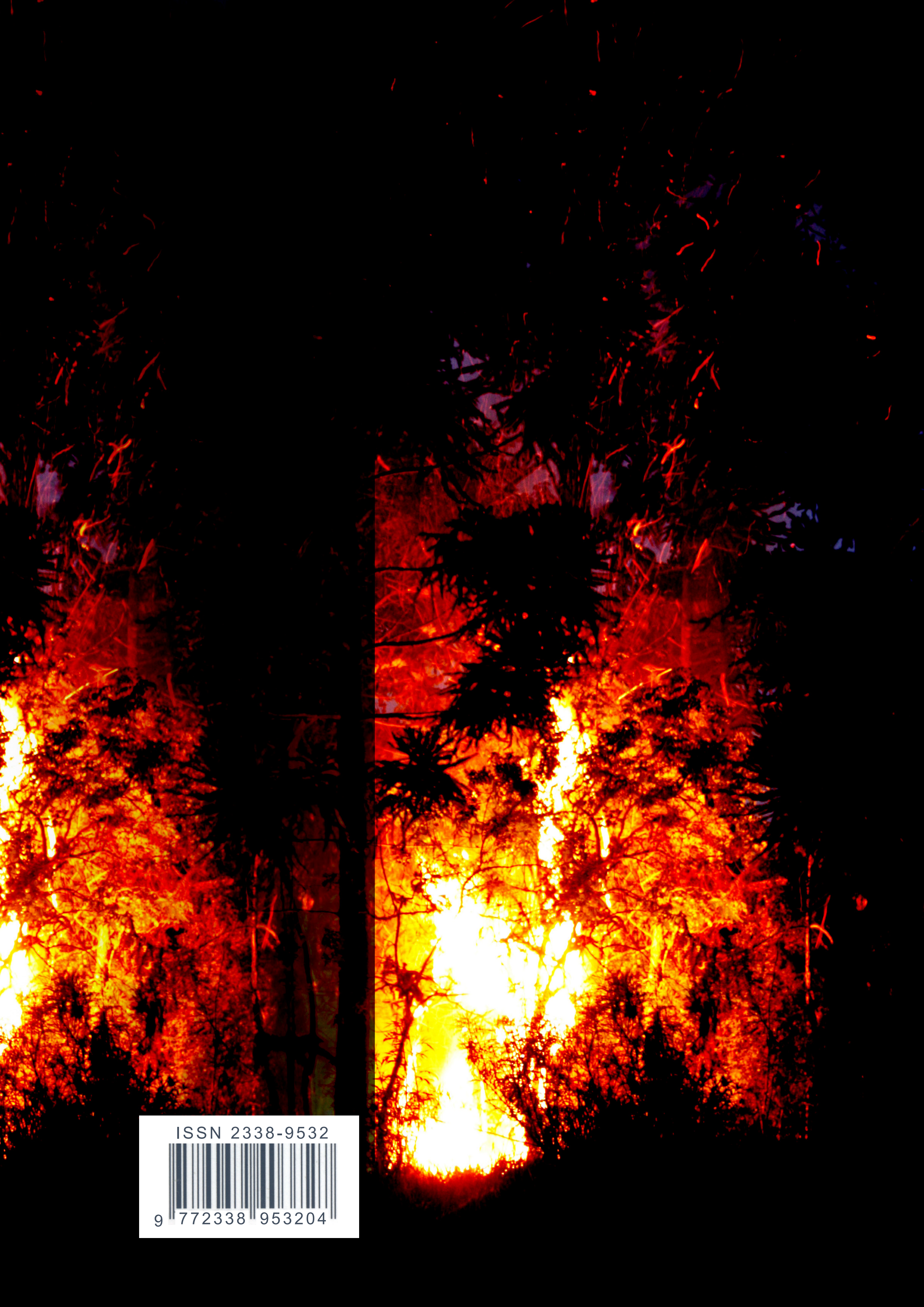
Scientific Name	Family (habit)	Vernacular Name (Language)	Usage	Category
Allium chinense	Alliaceae (grass)	Suna (Dayak Ngaju/Indonesia)	Vegetable, Medicine	F/Me
Eleutherina palmifolia	Alliaceae (grass)	Bawang Dayak (Indonesia)	Medicine	Me
Mangifera foetida	Anacardiaceae (tree)	Tuwe (Dayak Ngaju)	Poison fishing	O
Mangifera casturi	Anacardiaceae (tree)	Kasturi (Dayak Ngaju/Banjar/Indonesia)	Fruit	F
Dyera lowii	Apocynaceae (tree)	Jelutung (Indonesia)	Gum base	F
Calamus caesius	Arecaceae (rattan)	Rotan Taman(Indonesia)	Craft	M
Calamus manan	Arecaceae (rattan)	Rotan Manau (Indonesia)	Craft, Fruit	M/F
Calamus trachycoleus	Arecaceae (rattan)	Rotan Irit (Indonesia)	Craft, Vegetable	M/F
Auricularia sp	Auricularaceae (mushroom)	Kulat Bitak (Dayak Ngaju)	Mushroom	F
Stenochlaena palustris	Blechnaceae (fern)	Kalakai (Dayak Ngaju/Banjar)	Vegetable	F
Durio kutejensis	Bombaceae (tree)	Paken (Dayak Ngaju)	Fruit	F
Cordia sp.	Boraginaceae (tree)	Suji (Indonesia)	Food color	F
Garcinia mangostana	Clusiaceae (tree)	Manggis (Indonesia)	Fruit	F
Costus speciosus	Costaceae (grass)	Sawangkak (Dayak Ngaju)	Medicine	Me
Cucurbita moschata	Cucurbitaceae (vine)	Baluh / Labu Kuning (Dayak Ngaju/Indonesia)	Vegetable	F
Eleocharis dulcis	Cyperaceae (grass)	Purun (Dayak Ngaju/Banjar/Indonesia)	Craft	M
Dioscorea alata	Dioscoreaceae (vine)	Uwi (Dayak Ngaju/Indonesia)	Vegetable	F
Diplazium esculentum	Dryopteridaceae (fern)	Bajei (Dayak Ngaju)	Vegetable	F
Phyllanthus niruri	Euphorbiaceae (shrub)	Ambing buah (Banjar)	Medicine	Me
Flagellaria indica	Flagellariaceae (shrub)	Uwei Manyamei (Dayak Ngaju)	Medicine	Me
Fagraea crenulata	Gentianaceae (tree)	Kayu bulan (Dayak Ngaju/Banjar)	Medicine	Me
Hanguana malayana	Hanguanaceae (grass)	Bakung (Dayak Ngaju/Banjar)	Vegetable	F
Hygrocybe chlorophana	Hygrophoraceae (mushroom)	Kulat Siau (Dayak Ngaju/Banjar)	Mushroom	F
Curculigo villosa	Hypoxidaceae (grass)	Lemba (Dayak Ngaju)	Spice	F
Alseodaphne coriacea	Lauraceae (tree)	Gemor (Dayak Ngaju/Banjar/Indonesia)	Mosquito coil	O
Cinnamomum burmannii	Lauraceae (tree)	Kayu Manis (Indonesia)	Spice, Medicine	F/Me
Cinnamomum sintok	Lauraceae (tree)	Sintuk (Dayak Ngaju)	Medicine	Me
Leea indica	Leaceae (shrub)	Kayu Mali-mali (Dayak Ngaju/Banjar)	Medicine	Me
Termitomyces sp.	Lyophyllaceae (mushroom)	Kulat Bantilung (Dayak Ngaju)	Mushroom	F
Melastoma malabathricum	Melastomaceae (shrub)	Karamunting (Dayak Ngaju/Banjar)	Medicine	Me

Table Ethnic plant species in Central Kalimatan. Category: F-Food, Me-Medicine, M-Material, O-Others

Scientific Name	Family (habit)	Vernacular Name (Language)	Usage	Category
Aglaia sp.	Meliaceae (tree)	Kaja laki (Banjar)	Medicine	Me
Fibraurea chloroleuca	Menispermaceae (shrub)	Akar Kuning (Banjar)	Medicine	Me
Tinospora crispa	Menispermaceae (vine)	Akar gantung (Banjar)	Medicine	Me
Albertisia papuana	Menispermaceae (liana)	Sasungkai (Dayak Ngaju)	Spice	F
Antiaris toxicaria	Moraceae (tree)	Ipu (Dayak Ngaju)	Arrow poison	O
Artocarpus sp.	Moraceae (tree)	Pilang (Indonesia)	Fruit	F
Artocarpus champeden	Moraceae (tree)	Mangkahai (Dayak Ngaju)	Fruit	F
Artocarpus odoratissimus	Moraceae (tree)	Tarap (Dayak Ngaju/Banjar)	Fruit	F
Ficus microcarpa	Moraceae (tree)	Uhat jajangkit (Dayak Ngaju)	Medicine	Me
Ardisia sp.	Myrsiniaceae (shrub)	Butu tupai (Dayak Ngaju)	Medicine	Me
Melaleuca leucadendra	Myrtaceae (tree)	Galam (Dayak Ngaju/Banjar/Indonesia)	Building material, Charcoal	M/O
Tristaniopsis sp.	Myrtaceae (tree)	Palawan (Dayak Ngaju/Indonesia)	Medicine	Me
Nepenthes sp.	Nepenthaceae (grass)	Katupat Napu (Dayak Ngaju)	Ornamental plant	O
Grammatophyllum speciosum	Orchidaceae (grass)	Anggrek Tebu (Indonesia)	Ornamental plant	O
Areca catechu	Palmaceae (palm)	Pinang (Indonesia)	Betel nut	O
Baccaurea lanceolata	Phyllanthaceae (tree)	Kapul (Dayak Ngaju/Banjar)	Fruit	F
Piper betle	Piperaceae (vine)	Sirih (Indonesia)	Betel leaf	O
Dendrocalamus asper	Poaceae (bamboo)	Betung (Indonesia)	Vegetable	F
Cymbopogon citrates	Poaceae (grass)	Sarai/Serai (Dayak Ngaju, Banjar/Indonesia)	Spice, Medicine	F/Me
Pycnoporus coccineus	Polyporaceae (mushroom)	Kulat Merah (Dayak Ngaju)	Medicine	Me
Nauclea orientalis	Rubiaceae (tree)	Taya (Dayak Ngaju)	Vegetable	F
Myrmecodia pendans	Rubiaceae (epiphyte)	Sarang Semut (Dayak Ngaju)	Medicine	Me
Lavanga sarmentosa	Rutaceae (tree)	Saluang Belum (Dayak Ngaju)	Tonic, Medicine	F/Me
Viscum orientale	Santalaceae (tree)	Kayu Tungkun (Dayak Ngaju)	Medicine	Me
Dimocarpus malesianus	Sapindaceae (tree)	Tangkuhis (Dayak Ngaju)	Fruit	F
Nephelium maingayi	Sapindaceae (tree)	Katiau (Dayak Ngaju/Banjar)	Fruit	F
Nephelium sp.	Sapindaceae (tree)	Tanggaring (Dayak Ngaju)	Fruit	F
Schizophyllum commune	Schizophyllaceae (mushroom)	Kulat Karitip (Dayak Ngaju)	Mushroom	F
Eurycoma longifolia	Simaroubaceae (shrub)	Pasak Bumi (Indonesia)	Tonic, Medicine	F/Me
Solanum ferox	Solanaceae (grass)	Rimbang (Dayak Ngaju)	Vegetable	F

Table Ethnic plant species in Central Kalimatan. Category: F-Food, Me-Medicine, M-Material, O-Others

Scientific Name	Family (habit)	Vernacular Name (Language)	Usage	Category
Solanum torvum	Solanaceae (grass)	Segau (Dayak Ngaju)	Vegetable	F
Callicarpa longifolia	Verbenaceae (shrub)	Kitat Pusa/Sangkareho (Dayak Ngaju/Bakumpai)	Medicine	Me
Vitex pubescens	Verbenaceae (tree)	Kalapapa (Dayak Ngaju)	Medicine	Me
Alpinia galangal	Zingiberaceae (grass)	Langkuas/Laos (Dayak Ngaju/Indonesia)	Spice, Medicine	F/Me
Curcuma longa	Zingiberaceae (grass)	Henda/Kunyit (Dayak/Indonesia)	Spice, Medicine	F/Me
Etlingera hemisphaerica	Zingiberaceae (grass)	Potok (Dayak Ngaju)	Vegetable	F
Zingiber officinale	Zingiberaceae (grass)	Lai/Jahe (Dayak Ngaju/Indonesia)	Spice, Medicine	F/Me
?	? (tree)	Tadangkak (Dayak Ngaju)	Medicine	Me
?	? (fern)	Tagentu (Dayak Ngaju)	Medicine	Me



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