Asia-Pacific Network for Global Change Research

Vulnerabilities of the Carbon-Climate System: Carbon Pools in Wetlands / Peatlands as Positive Feedbacks to Global Warming

Final report for APN project 2005-12-NSY-Parish

The following collaborators co-led this project:

Faizal Parish, Global Environment Centre, Malaysia, fparish@genet.po.my

Pep Canadell, Global Carbon Project, Australia, pep.canadell@csiro.au

Vulnerabilities of the Carbon-Climate System:
Carbon Pools in Wetlands/Peatlands as Positive Feedbacks to Global Warming

2005-12-NSY-Parish

Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

Ecosystem responses that cause carbon loss to the atmosphere as a result of warmer climates and land use changes could greatly accelerate climate change during this century. Potentially vulnerable carbon pools that currently contain hundreds of billion tons of carbon could release as much as 200 ppm of atmospheric CO_2 during this century, so rivaling the expected release from fossil fuel combustion. Tropical peatlands in Se Asia store an estimated 50-90 Gt Carbon. Degradation especially from drainage and fires have led to releases of approximately 500 million tones of carbon each year over the past decade - equivalent to approximately 10% of global fossil fuel emissions over the same period. The project aimed to (i) quantify the extent and carbon content of tropical peatlands in the Asia Pacific region, (ii) analyze the risk of large releases of carbon from peatlands over this century, and the potential impact on global warming.

Objectives

The main objectives of the project were:

1. To compile and synthesize existing datasets on carbon content of tropical peatlands in the Asia Pacific region.
2. To assess the processes affecting the balance and release of C, including the identification of potential “thresholds” that push the system rapidly to dangerous climate change.
3. To test model algorithms for integrating the carbon dynamics of tropical peatland pools in terrestrial C models.
4. To develop a first-order analyses of the possible net C emissions from peatlands under different IPCC-SRES scenarios.
5. To develop a first-order analyses of the plausible positive feedback to global warming.

Amount received for each year supported and number of years supported

USD 45,000.00 (Aug 2005 – Aug 2006)

Participating Countries

Participants from the following APN countries were involved in the project activities: Australia, China, Indonesia, Japan, Malaysia, Papua New Guinea, Thailand, The Philippines and the USA, Participants from non-APN countries (funded by other sources) were from Denmark, Finland, Germany, Netherlands and United Kingdom .

Work undertaken

Among the first activities undertaken was the compilation of information relating to the extent and carbon content of peatlands in SE Asia and the associated GHG fluxes. In addition the vulnerability of these carbon stores to land use and climate change was assessed. This was done first through electronic consultation followed by the organizing of the 1st workshop in Pekanbaru, Indonesia from 23-26 January 2006 attended by 60 participants from 12 countries. More than 25 presentations were made during the three days workshop.

At the first workshop six major syntheses were designed which will form part of a special issue in the Springer journal of ECOSYSTEMS. The synthesis outlines were developed and agreed, and various small working groups are now in the writing stages to be completed by the end of 2006. Among the various syntheses, the largest effort has been in the topics of peatland distribution and C stocks, fire, C fluxes, and future trajectories of C emissions under different management and climate scenarios.

The workshop also identified critical gaps for long term research which resulted in the encouragement, and successful submissions, of two new proposals to SARCS and EU. Among the various gaps identified, one of the uncertainties in the full carbon budget of peatlands under land use and climate change is the lateral transport of dissolved and particulate organic carbon via canals and rivers to the sea margins, and the fate of the carbon when it gets there (This will be assessed in the additional study to be supported through SARCS - see below Results point 3).

Another aspect of this project was the establishment of a team of peatland/climate/carbon flux experts forming a special working group to specifically develop analyses of possible futures for tropical peatlands and their contribution of carbon emissions over the next 100 years. The analyses using the PEAT CO_2 model combine two approaches for a global analysis using existing datasets, new process understanding, land use and climate change scenarios, all combined with a modelling framework developed during the first workshop. This working group met in the 2nd workshop in Kuala Lumpur from 26-27 August 2006 to further develop the modeling tool with regards to water table depth and vulnerability to fire, management scenarios for the next 15 and 30 years, as well as climate projections.

Results

1. Riau declaration on peatlands and climate change (Appendix 2)
2. New synthesis on the extent, depth, and carbon content of peatlands in Southeast Asia.
3. Successful application "Patterns and Seasonal Variability of Carbon Contents in Kapuas River" by Gusti Anshari to SARCS.
4. Successful application "Carbon-Climate-Human Interactions in Tropical Peatlands: Vulnerabilities, Risks and Mitigation Measures (CARBOPEAT)" by Susan Page and to European Community.
5. Inclusion of sub-component on peatlands and climate change in proposal on Rehabilitation and Sustainable Use of Peatlands in Se Asia submitted to IFAD-GEF by GEC and ASEAN
6. Preparation of a special issue in ECOSYSTEMS (Appendix 2).
7. Preparation of a new APN proposal on Mitigation and Adaptation in tropical peatlands.
8. Compilation of Proceedings from workshop in Pekanbaru (See abstracts from the workshop in Appendix 4)

Relevance to APN scientific research framework and objectives

This project addressed four of the major interest research areas of APN in the following way: Global warming due to fossil fuel emissions and land use will change the hydrological cycle of wetlands/peatlands ("Changes in Costal Zones and Inland Waters"), so impacting on the dynamics and C fluxes in and out of the system ("Changes in Terrestrial Ecosystems"). Increased C fluxes from wetlands will increase atmospheric CO_2 concentrations ("Changes in atmospheric Composition"), feeding back positively to global warming ("Climate Change & Variability") which in turn will further increase C emissions from wetlands.

Self evaluation

This project has been very successful and exceeded expectations as what we could do with the modest funding, largely thanks to the intense cooperation among groups around the world who provided information and committed resources and scientists for the meeting in Pekanbaru, and in-kind support for the subsequent synthesis efforts and model tool development. The relevance and quality of the products have been proved by the acceptance by a renowned international ISI journal (Ecosystems) with an Impact Factor of 3.5 to publish the various syntheses resulting from this project.

In addition, the following stakeholders have all made explicit their interest to be informed on the outcomes of this project:

- the Association of South East Asian Nations (ASEAN)
- the central and provincial governments in Indonesia, and national government of other SE Asian countries with significant peatlands
- the pulp and paper industry in Indonesia which is involved in peatland management
- National and International NGOs WWF International and Indonesia
- Research institutions and networks in the region

It is this broad interest in the main outcomes of the project from policy makers to industry that shows the relevance and the importance of continuing this work in the future.

Potential for further work

The group designed a number of synthesis efforts that will result in a set of peer-reviewed papers and databases for use by the large research and policy communities. The synthesis although well advanced during the 12 month period of the APN proposal will need to continue for another 6-9 months after. The specific synthesis efforts that require the most development in the immediate future are:

- Synthesis of existing data on extent and carbon content of tropical peatlands.
- Synthesis of factors controlling carbon exchange in pristine and disturbed peatlands.

Potential work also includes identifying and assessing the effectiveness of climate change mitigation and adaptation options for tropical peatlands through data gathering, workshops and preparation of a number of peer-reviewed papers

Besides, it would also be possible for develop an interactive web-based tool for support decision making on mitigation and adaptation options for peat, and at the same time to strengthen links and cooperation between individual and agencies working on peatlands and climate change in the region of South East Asia.

Publications

1. CD-ROM Proceedings of Workshop on Vulnerability of Carbon Pools of Tropical Peatlands in Asia, 23-26 January 2006
2. Report of Workshop on Peatland and Climate Change in Kuala Lumpur, 26-27 August 2006
3. Special Issue in the Springer journal of ECOSYSTEMS (to be published in 2007).

Acknowledgments

In addition to the support from APN which made this project possible – we would like to thank the following organization/institution for their contribution and support to this project; CIDA, CIFOR, UNEP-GEF, WL Delft Hydraulics, Wageningen University, Hokkaido University, Kalteng Consultant, Max Plank Institute, University of Helsinki, Chiba University, Riau Andalan Pulp and Paper, Center for Remote Sensing Application and Technology Development, National Institute of Aeronautics and Space (LAPAN), Jakarta, University of Leicester, Seameo Biotrop, Department of Agriculture Sarawak, Bogor Agricultural University, Universitas Tanjungpura, Agency for the Assessment and Application of Technology, BPPT, CSIRO Tropical Forest Research Centre, Forest Research Institute Malaysia, Wetlands International-Indonesia Programme, Wetlands International -Thailand programme, Lambung Mangkurat University & Gadjah Mada University.

Technical Report

Preface

The APN- supported project on Vulnerabilities of the Carbon-Climate System: Carbon Pools in Wetlands/Peatlands as Positive Feedbacks to Global Warming was undertaken in the period August 2005-August 2006 under the joint leadership of the Global Environment Centre (based In Malaysia) and the Global Carbon project (based in Australia). The purpose of the project was to bring together interested experts from the Asia pacific Region and elsewhere in the world to share knowledge on the importance and vulnerability of tropical peatland carbon stores and their potential impact on future climate change. Tropical peatlands in Se Asia store an estimated 80-110 Gt Carbon. Degradation of peatlands especially from drainage and fires lead to releases of approximately 0.5 Gt Carbon each year over the past decade equivalent to 10% of global fossil fuel emissions over the same period. This will have a significant positive feedback to global warming. The project has initiated important work to bring together key experts to address this issue. However significant additional efforts will be needed to determine the situation in further detail and to initiate measures to control the situation. We hope that readers of this report will thus be supportive of continuing efforts in this important area.

Faizal Parish, Global Environment Centre and Pep Canadell, Global Carbon Project

Table of Contents

1.0 Introduction

Recent modeling simulations have shown the major potential role of previously undocumented positive feedbacks between warming and the terrestrial C cycle in driving climate change during the 21st Century (Cox et al. 2000; Dufresne et al. 2002; Friedlingstein et al. 2003).

The findings showed that CO_2 releases stimulated by warming accelerate warming and further CO_2 releases well above what is currently predicted by the IPCC (2001). In these studies, the major loss of C from vulnerable pools were from tropical forest by fire (interacting with land use change) and soil C by increased decomposition. The experiments to date, however, are too limited to support an accurate quantification of these positive feedbacks, but the range of the results highlights the importance of further assessments.

A literature analysis documents the existence of a number of vulnerable C pools both on land and in the oceans, with the potential for major C release to the atmosphere in the order of several hundred Petagrams (1 Pg = 1 billion tones) during this century (Gruber et al. 2004; Canadell et al. 2004). Such a massive release of greenhouse gases to the atmosphere would result in higher concentrations of atmospheric CO_2, accelerating climate warming, and potentially stimulating even greater losses of carbon from vulnerable pools.

Wetlands including peatlands are one of the largest reservoirs of biospheric carbon in the Earth system, which have resulted from thousands of years of carbon accumulation with minimal decomposition due to the anaerobic and often acidic soil conditions. Low temperatures also play an important role in the case of high latitude wetlands which store about 455 PgC (IPCC 2001), with the largest area being in Russia and Canada. In fact, recent new estimates of Siberian peatlands using high-resolution GIS-based inventories have shown peatlands to be more extensive and to have accumulated 25% more C than previously reported (Sheng et al. 2004).

Tropical peat swamps are much less known, but it is estimated that Indonesian peatlands alone store up to 70 Pg C, with reservoirs up to 25 meters deep. Unlike boreal wetland/peatlands, emissions from tropical peatlands are strongly linked to the interaction between land use change (ie, drainage and deforestation) and climate change (most important ENSO events). Fires in peat swamps and associated forests in Indonesia during the 1997-98-El Nino dry season emitted an estimated 0.81 to 2.57 Pg C to the atmosphere, the equivalent of 13% to 40% of the mean annual global carbon emission from fossil fuels (Page et al. 2002).

For tropical peatlands in the Asia Pacific region, destabilization drivers (warming and land use change) conducive to increase net C emissions have shown some of the highest rates in the world and are expected to continue so for decades to come. With respect emissions from tropical wetlands, the most important driving forces is the drainage and degradation of peatlands and subsequent increased C emissions (interactively with ENSO-enhanced fires). Rates of forest conversion into agricultural land (plantations and foodcrops) in Southeast Asia are amongst the highest in the world and these trends are predicted to continue so for a number of decades (IPCC-SRES 2000).

None of these major C pools with their associated extent and C content are thoroughly addressed in current ecosystem or climate models. As a consequence, it has not yet been feasible to estimate either the probability of the changes or the likely C emissions. Still, ignoring the potential for these large releases is not responsible, and the vulnerability of the climate system to them should be explored.

Similarly, there has been no comprehensive analysis of the size of vulnerable pools on land, and their potential dynamics during this century; nor is there an assessment of their possible collective feedbacks to climate change. The biggest obstacles to progress are the lack of (i) spatially explicit data on the sizes of the pools, and (ii) credible algorithms for simulating the vulnerability of these pools to climate change.

2.0 Methodology

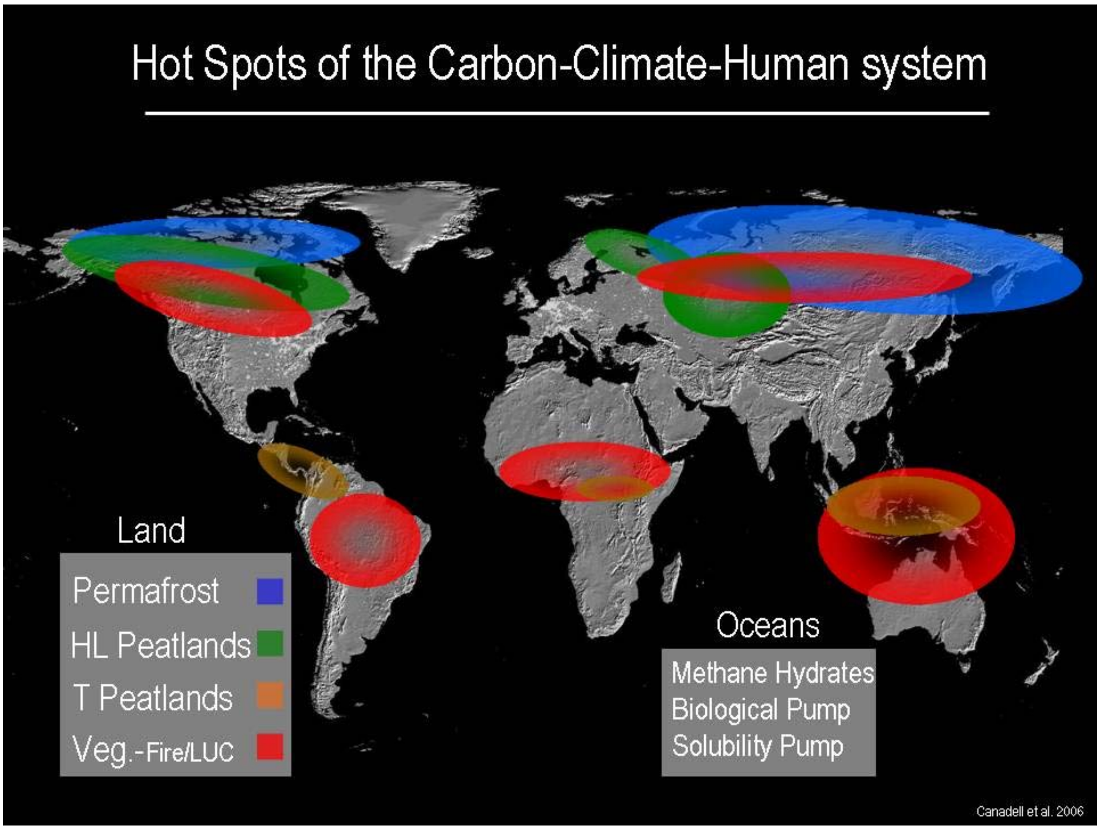
The main methodologies used to achieve the objectives above were :

- Data gathering and synthesis on tropical peatland extent and potential carbon store
- Gathering and synthesis information on Greenhouse gas emissions from tropical peatlands in Se Asia and identification of key control processes for GHG emissions in peatlands
- Inter-comparison of General Circulation Models (GCM) to analyze precipitation outputs for Indonesia at the end of 2100.
- Analyses of possible carbon emissions using selected scenarios of land use and climate change with appropriate biogeochemical modeling tools for wetland ecosystems.
- Broader discussions on key datasets, research questions, and identification of knowledge gaps.

3.0 Results & Discussion

i. Main findings

Tropical peatlands, particularly the lowland peatlands in Southeast Asia, are significant hot-spots for carbon-climate feedbacks as seen during El Nino years in areas with high deforestation and drainage rates and widespread peatland fires. Current management practices in peatlands combined with climate change and variability are having a major negative impact on peatland carbon pools. In the past 10 years about 3 million ha of peatland in SE Asia have been burnt releasing 3-5 billion tonnes of carbon. In addition, the drainage of peat for oil palm and timber and pulpwood plantations as well as other agriculture and unsustainable logging is estimated to have affected more than 6 million ha and released an additional 2 billion tonnes of carbon over the same period. Thus the emission of carbon dioxide from peatlands in SE Asia represents one of the largest single sources of GHG emissions globally and is equivalent of 10% of the average global fossil fuel emission over the same period. This is accelerating global climate change.



- The project has helped to gather and significantly improve the information on the extent of peatlands in the Se Asia region. In particular the project has helped to collate new information on the extent of peatlands in Indonesia and Papua New Guinea.

Table 1: Changes in estimates of Lowland Peatland Area in Se Asia following data collation and analysis by the project

COUNTRY	Estimate of Peatland area before project (ha)	Estimate of Peatland area after project (ha)
INDONESIA	14,000,000 – 27,000,000	21,250,500
PAPUA NEW GUINEA	1,000,000-2,000,000	6,500,000- 7,000,000
MALAYSIA	2,500,000	2,500,000
BRUNEI	100,000	100,000
THAILAND	64,500	64,500
VIET NAM	25,000-180,000	36,000
PHILIPPINES	500-2000	11,000
LAO PDR	-	100 – 20,000
MYANMAR	-	3500
SINGAPORE	-	1
CAMBODIA	-	No data
Total	**17,690,500-31,857,000ha**	**30,465,100-30,985,000**

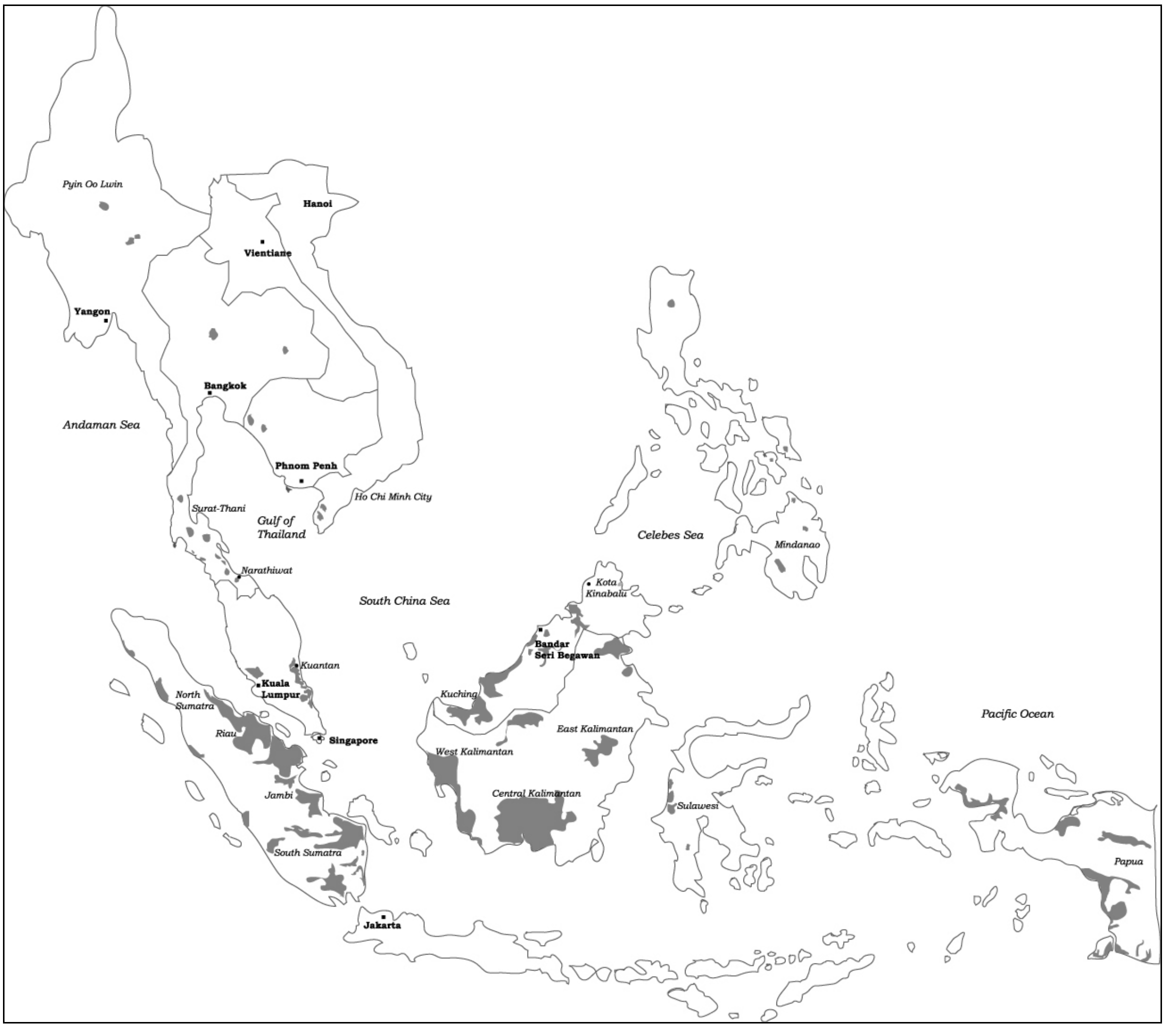
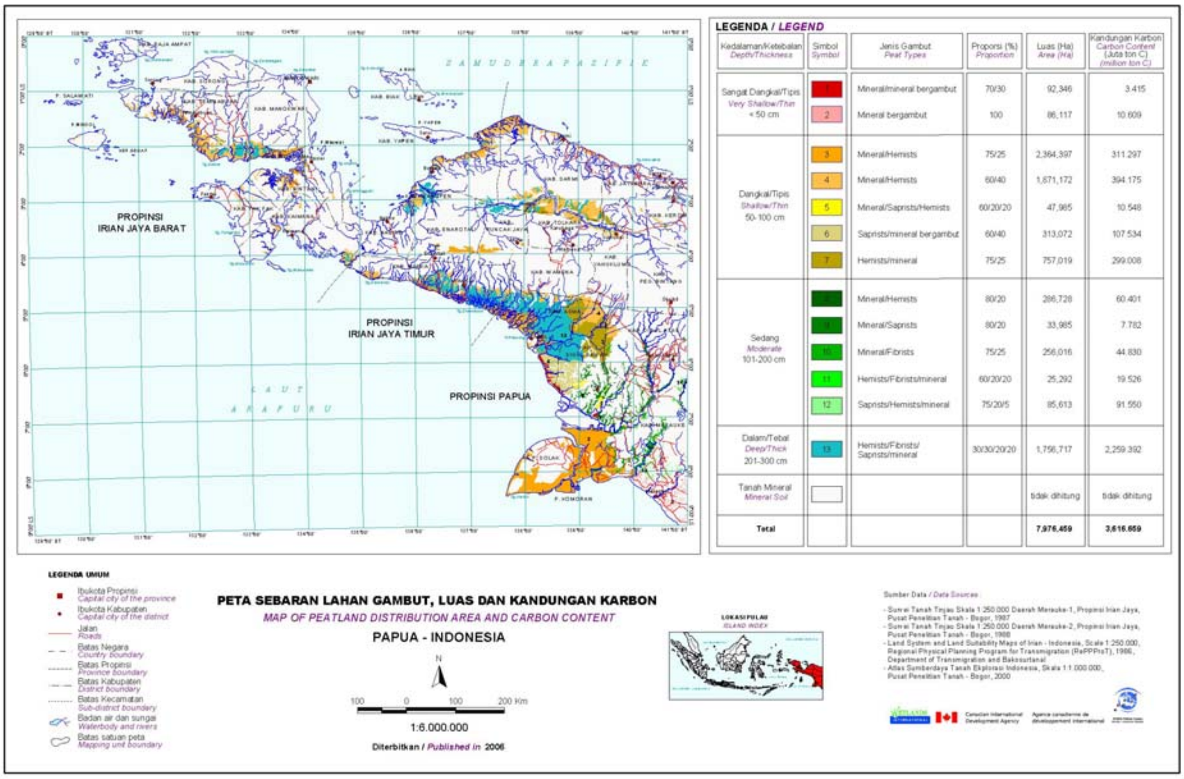


Figure: Peatland Distribution in South East Asia

- Significant progress was made during the project period in clarifying the extent of peatlands in the Western Portion of Papua Island. This work was primarily funded by the related project on Climate change Forest and peatland in Indonesia (CCFPI) but funds from APN supported some key aspects. Prior to the study there was a lack of clarity on the extent of peat soils in this region with estimates ranging from 500,000 ha to 10,000,000 ha. The new assessment was able to confirm the extent as being 7,976,500 ha. Maps were produced on the extent and estimated thickness of the peat deposits.



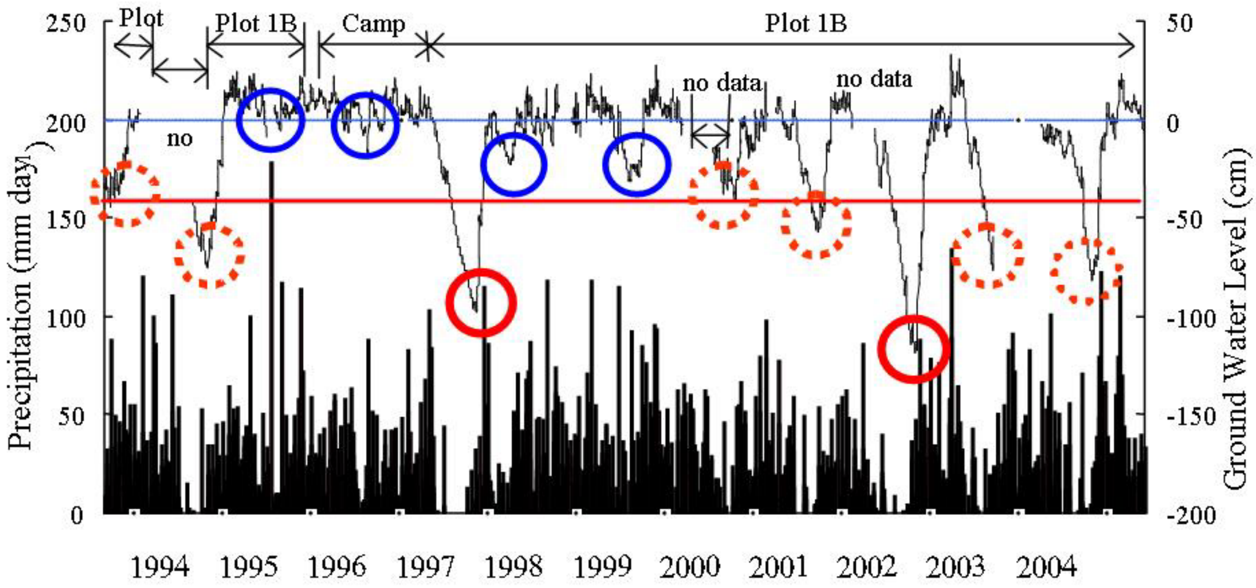
- The project was able to collate and generate new estimates on the carbon stocks in peatlands in the region The total carbon store estimated to be in the peat pool was 42.31 billion tonnes. This represents about 7.5% of the global peatland carbon pool. In addition the above ground vegetation is estimated to hold an additional 4-5 billion tonnes. There is still significant uncertainty about the stock especially in Papua province of Indonesia and Papua New Guinea where additional surveys are required to asses the depth of the peat deposits. There is also a need to look further at the stocks in extremely deep peats in Sumatra, Kalimantan and Malaysia where peats of over 20 m are recorded.

Region	Area of peatland (ha)	Estimated Carbon stock in peat (billion tonnes)
Sumatra (Indonesia)	7,204,300	18.810
Kalimantan (Indonesia)	5,769,200	11.270
Papua (Indonesia)	7,976,500	3.620
Papua New Guinea	6,500,000	2.923
Malaysia	2,630,000	5.260
Other countries/areas	525,000	0.42
Total	30,475,000	42.31

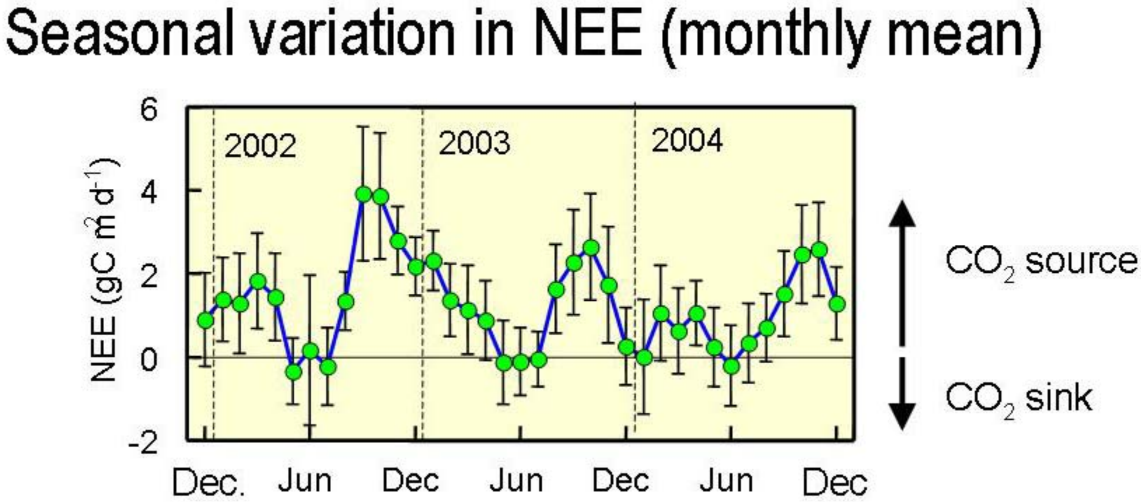
Table to show estimated carbon stock in peat soil in different parts of Se Asia

- Information was also compiled on the trends in peatland extent and carbon stock. In Indonesia, studies by the Bogor Soil Institute and Wetlands International - Indonesia have indicated that there has been a serious decline in the carbon stocks in peatlands in Sumatra between initial surveys in 1990 and further surveys in 2002. The total decline in the carbon stock in peatlands over that period is estimated to be 3.5 billion tonnes of Carbon or an average of 290 million tones per year. The reduction in carbon stock is closely linked to large scale drainage and conversion of peatlands to agricultural land and extensive peatland fires following logging and drainage. Studies were also conducted by the Agriculture department in peninsula Malaysia this indicated a decline in the area of peatlands between initial soil surveys in 1960 and more detailed soil surveys in the 1990. Although some of the differences could have been due to the different level of detail of the studies a significant portion of the change is due to the reduction in peat soils due to their clearance, drainage and conversion to agriculture. As a result shallow peats have totally degraded and some deeper peats have become peaty soils.

- Information on the possible thresholds related to peatland fires. Changes in the water table depth either due to management or changes in precipitation/evaporation largely controls the susceptibility of peatlands to fire. Figure shows for South Kalimantan (Borneo) in solid red circles the years of big fire seasons, dash red circles of moderate fire years, and blue circles of no fire occurrence (Takahashi 2006, unpublished, part of the synthesis papers). There appears to be a threshold water depth of about 40cm below which the peatland becomes increasingly susceptible to fire and the associated large scale release of the major carbon store.



- Even when there is no fire, the water table fully controls the exchange of vertical carbon fluxes between vegetation+soil and the atmosphere. A new synthesis of unpublished data on eddy covariance flux measurements showed that a 30 m tall relatively pristine forest which has been drained at the boundaries has turned into net permanent source of carbon emission (Takashi et al. 2006, unpublished, part of synthesis). Given some of the peatlands are up to 12 m deep, the sources of carbon will remain active until the peatland disappears or drainage stops as peatland subsides.

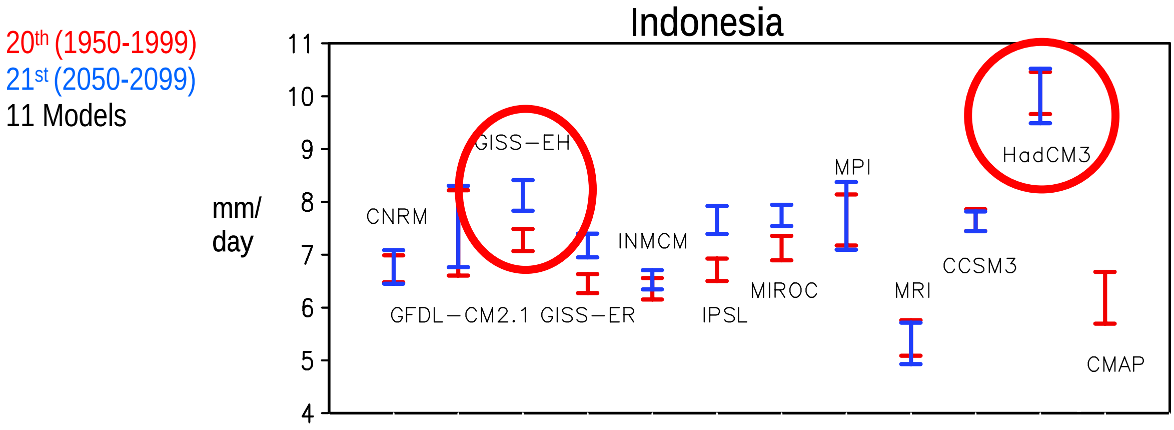


Net emissions of Carbon from partly drained (but intact) forest in Central Kalimantan based on Eddy covariance flux measurements

- CO2 Emissions from fire and drainage of peatlands in South East Asia are now a significant global source of emissions. Analyses using the PEAT CO2 model have indicated that the CO2 emission due to oxidation following peatland drainage is 436 Mt/y (fires excluded), or 63% of global emissions from this source. This is assuming an estimated drained area of 6 million ha and an average drainage depth of 0.8m. It should be noted that not only is the emission of 436 Mt/y 63% of global emissions, but it is in fact equivalent to 1.8% of the global CO2 emissions from fossil fuel burning (24 Gt/y in 2000). Considering the very high rate of peatland development in especially Indonesia, the drained area and CO2 emission by 2005 will be significantly higher, and may well double before 2020.

- Fires have affected about 3 million ha of peatlands in Se Asia in the last decade; emissions reported for the 1997 fires alone were 0.81-2.57 Gt Carbon or between 15 to 40% of global emissions from global fossil fuel burning. Peatland fires are often related to drainage - for agriculture or for logging. Through inclusion of emissions related to fires – anthropogenic CO2 emissions from peatlands in the region could be as much as 1,500 million tones per year.

- In order to assess the potential impacts of future climate changes, an assessment was made of the changes predicted by the different climate models. Twelve fully coupled General Circulation Models were compared for their output for precipitation at the end of 2100 over Southeast Asia to predict the possible effects of climate change in the net carbon exchange of tropical peatlands. Although only some models showed a clear overall decrease in total precipitation by the end of the century, models that showed no annual changes did show a decrease precipitation during the dry season and an increase precipitation during the wet season. The result is that that there is a distinct possibility that in Southeast Asia, particularly Indonesia where most of the peatland is, the dry season and their associated fire activity will be more intense and longer compounded by the fact that given the background air temperature is warming rapidly in all models (Wenhong Li, unpublished, part of synthesis)



Predicted daily average rainfall in Indonesia according to different GCM Models compared to average rainfall 1950-1999.

ii. Discuss the importance of your findings, in light of the overall study aims.

The findings of the study are rather important as they provide significant new information on the extent of tropical peatlands in Se Asia and their importance for carbon storage. They also reveal that the carbon stores from tropical peatlands are easily degraded through clearance, drainage and fires and that tropical peatlands are now a major source of emissions of global significance. Initial analysis of the results of GCMs indicates that the future stress on peatland carbon pools is likely to increase through future climate change with rising temperatures combined with lower dry season rainfall adding to the stress on peatland systems. The findings have enabled significant progress towards the overall study aims.

Two significant findings which will have implications for future assessments of emissions are:

i) vulnerable pools of carbon in tropical peatlands are more extensive and contain more carbon than originally anticipated, and therefore the size of the possible carbon-climate impacts could be more significant;

ii) even in the absence of deforestation, drained peatlands are net carbon sources making the impact of drainage and deforestation larger than accounted in book keeping books to calculate carbon emissions from tropical deforestation (without counting the increase in fire susceptibility of drained forests which under pristine conditions have developed no adaptation to dry soils)

iii. Synthesize what has (and has not) been learned about the problem and identify existing gaps.

Although we can close the carbon budget and assess the effects of land management and climate change at the stand and site level, we are not yet able to close the full carbon budget in a large scale largely because we are missing information on the lateral transport fluxes. We have tried to get around this problem by working on peat subsidence which is loss of peatland depth as decomposition occurs after the initial compaction. In this case, is less relevant to understand how the carbon was lost but it remains a key problem to attribute apparent loss of peat due to compaction from that of decomposition. In addition, and in order to constrain our measurements we will need to have a much better sense of the loss of carbon through riverine transport and its final fate in estuaries and the sea margins.

There is also a need to understand in more detail the potential climate related changes which may occur in the future. A major factor leading to long droughts in the region is the ENSO effect in the Pacific as well as the Indian Ocean Dipole. Both these mechanisms are a major driver of large scale peat fires – a major source of peat degradation and associated GHG emissions. Further information needs to be gathered on how these processes interact and how they may be influenced by future climate changes or combine with future climate change to reduce peatland sequestration and storage.

The project was not able to make sufficient progress to test model algorithms for integrating the carbon dynamics of tropical peatland pools in terrestrial C models and to develop a first-order analyses of the possible net C emissions from peatlands under different IPCC-SRES scenarios. This work will need to be developed further in the future.

iv. Recommend areas for further work.

The group designed a number of synthesis efforts that will result in a set of peer-reviewed papers and databases for use by the large research and policy communities. The synthesis although well advanced during the 12 month period of the APN proposal will need to continue for another 6-9 months after. The specific synthesis efforts that require the most development in the immediate future are:

- Synthesis of existing data on extent and carbon content of tropical peatlands.
- Synthesis of factors controlling carbon exchange in pristine and disturbed peatlands.
- Analysis of impacts of future climate change

Among the various gaps identified, one important uncertainty in the full carbon budget of peatlands under land use and climate change is the lateral transport via canals and rivers to the sea margins, and the carbon fate when it gets there.

In addition more work is needed to test model algorithms for integrating the carbon dynamics of tropical peatland pools in terrestrial C models and to develop a first-order analyses of the possible net C emissions from peatlands under different IPCC-SRES scenarios.

Potential further work recommended includes identifying and assessing the effectiveness of climate change mitigation and adaptation options for tropical peatlands through data gathering, workshops and preparation of a number of peer reviewed papers.

One future opportunity would be to develop an interactive web-based tool to support decision making on mitigation and adaptation options for peat. In addition there is a need to strengthen links and cooperation between individual and agencies working on peatlands and climate change in the region of South East Asia.

4.0 Conclusions

i. Key findings and conclusions from the study are as follows:

- Peatlands in Southeast Asia, are significant hot-spots for carbon-climate feedbacks in areas with high deforestation and drainage rates and widespread peatland fires.

- Current management practices in peatlands combined with climate change and variability are having a major negative impact on peatland carbon pools.

- Peatlands cover approximately 31 million ha in Se Asia and store and estimated 47 Gt of Carbon.

- Peatland carbon pools in the region are be severely impacted by drainage (affecting over 6 million ha) and fire (affecting over 3 million ha). Drainage may release 100 tonnes of CO2 per ha per year while a single fire event may release up to 2,400 tonnes of CO2 per ha/ fire event.

- Peatlands in the region are emitting up to 1.5 Gt of CO2 each year as a result of anthropogenic activities such as land clearance and conversion, drainage and fire. This represents a major global source of GHG emissions.

- Approximately 3 million ha of peatlands in the region have been drained for agriculture or logging and then abandoned. These areas are particularly susceptible to peat fires.

- Slight drainage is able to stop carbon sequestration in apparently healthy forests – turning important carbon sequesting systems into significant carbon emitters.

- A critical threshold linked to the increase in fire occurrence in peatlands is the depression of the water table by more than 40cm below the peat surface. This happens as a result of drainage for agriculture or plantations (drainage regimes for crops vary between 20cm-1.5 m with an average of about 80cm) as well as through increasing evapotranspiration rates.

- Future climate change scenarios for the region indicate there with be a combination of increased temperatures and reduced rainfall in the dry seasons. This is likely to lead to a reduction in the net water tables in peatlands and lead to greater carbon emissions due to decomposition of the peat layer and also through increased number of fires.

- With growing population and economies in the region the demand for land is increasing and more peatlands arte being cleared and converted for agriculture. This is reducing the number of natural peatlands to sequest carbon and also increasing the carbon emissions as a result of drainage and fires.

5.0 Future Directions

The partnership group established for the implementation of the project has identified a number of new directions including:

New Research Proposals

The submission of a proposal to APN for possible funding in 2007-2008 with the topic on adaptation and mitigation options for tropical peatlands to reduce GHGs emission.

Collaboration in the implementation of other research projects including

- Patterns and Seasonal Variability of Carbon Contents in Kapuas River led by the University of Tanjungpura and supported by SARCS.

- Carbon-Climate-Human Interactions in Tropical Peatlands: Vulnerabilities, Risks and Mitigation Measures (CARBOPEAT) led by University of Leicester and supported by the European Community.

- Sub-component on peatlands and climate change in proposal on Rehabilitation and Sustainable Use of Peatlands in Se Asia lead by the ASEAN Secretariat and submitted to IFAD-GEF

Policy and management

Major concerted efforts are needed between the governments, researchers, private sector and local communities to enhance the management of peatlands to provide sustainable livelihoods and decrease the emissions of CO2 from fires and drainage and as far as possible protect intact peatlands for their carbon sequestration and storage functions.

Information and Outreach

Enhance the collation and dissemination of information on peatlands and climate change in South east Asia through the organisation of meetings and workshops; dissemination through the SE Asia peat Network (550 members) as well as web sites eg www.peat-portal.net .

References

All materials presented in this report are still unpublished. The key main outlet for publication will be the special issue in ECOSYSTEMS although other independent papers are also being prepared.

Glossary of Terms

C – Carbon

CH_4 – Methane

CIFOR - Center for International Forestry Research

CO_2 – Carbon dioxide

ENSO – El Nino Southern Oscillation

GCP – Global Carbon Project

GEC – Global Environment Centre

GIS – Geographical Information System

IPCC – Intergovernmental Panel on Climate Change

Pg – Petagrams

RAPP - Riau Andalan Pulp and Paper

SRES – Special Report on Emissions Scenarios

WWF – World Wildlife Fund for Nature

Appendix 1 Funding sources outside the APN

<u>Co-funding</u>

Centre for International Forestry Research (CIFOR)

CIDA supported project on Climate change Forest and Peatland in Indonesia

Global Carbon Project (GCP)

Global Environment Centre (GEC)

Wetlands International

Joint project of Wetlands International and GEC on Integrated Management of Peatlands for Biodiversity and Climate Change (funded by UNEP-GEF);

Joint Project of Wildlife Habitat Canada, Wetlands International and GEC on Climate Change Forests and Peatlands in Indonesia (funded by CIDA -CCDF)

WL Delft Hydraulics

<u>In-kind support</u>

Agency for the Assessment and Application of Technology, BPPT

Australian National University

Bogor Agricultural University

BOS Foundation

Center for Remote Sensing Application and Technology Development

Chiba University,

CSIRO Tropical Forest Research Centre

Department of Agriculture Sarawak

Forest Research Institute of Malaysia (FRIM)

Hokkaido University

Jikalahari

Kalteng Consultant,

Max Plank Institute,

Ministry of Environment Indonesia

National Institute of Aeronautics and Space (LAPAN), Jakarta

Riau Andalan Pulp and Paper/APRIL

Riau Provincial government

Seameo Biotrop,

University of Helsinki,

University of Leicester

Universitas Tanjungpura

Wageningen University

WWF

Appendix 2: Riau Declaration on Peatlands and Climate Change

The Workshop on Vulnerability of Carbon Pools in Tropical Peatlands was held in Pekanbaru, Riau, Sumatra from 23-26 January 2006. It was attended by 61 participants from 12 countries. It was organised by the Global Carbon Project (GCP), the Global Environment Centre (GEC) and the Centre for International Forestry Research (CIFOR). It reviewed the extent of and carbon store in tropical peatlands, land use change and fire, greenhouse gas (GHG) emissions, future climate scenarios and management options. A field visit to the Kampar Peninsular to assess current peatland plantation management practices was facilitated by APRIL/PT Riau Andalan Pulp and Paper. The workshop was supported by The Asia Pacific Network for Global Change (APN); the joint project of Wetlands International and GEC on Integrated Management of Peatlands for Biodiversity and Climate Change (funded by UNEP-GEF); and the joint Project of Wildlife Habitat Canada, Wetlands International and GEC on Climate Change Forests and Peatlands in Indonesia (funded by CIDA); GCP and CIFOR.

The workshop noted that peat is one of the world's most important carbon stores (storing about 30% of global soil carbon) and tropical peatlands are an extremely important component – storing 30% of peatland carbon. The most extensive tropical peatlands are in SE Asia and cover about 30 million ha of which over 20 million ha are in Indonesia and 4 million ha in Riau province.

Tropical peatlands play an extremely important global role for carbon storage and climate moderation as well as providing a range of other benefits such as biodiversity, water management, and livelihood support to local communities. The fundamental component of peatlands is water. As water level decreases in peatlands so does capacity for sequestering and storing carbon.

Current management practices in peatlands combined with climate change and variability are having a major negative impact on peatlands. In the past 10 years about 3 million ha of peatland in SE Asia have been burnt releasing 3-5 billion tonnes of carbon. In addition, the drainage of peat for oil palm and timber and pulpwood plantations as well as other agriculture and unsustainable logging is estimated to have affected more than 6 million ha and released an additional 2 billion tonnes of carbon over the same period. Thus the emission of carbon dioxide from peatlands in SE Asia represents one of the largest single sources of GHG emissions globally and is equivalent of 10% of the average global fossil fuel emission over the same period. This is accelerating global climate change.

It is recognized that unsustainable practices in management of peatlands in SE Asia is the main cause of peat fires and associated transboundary smoke haze in SE Asia which causes massive health, social, economic and environmental impacts.

Subsequent El Niño events will increase likelihood of drought and associated fires will have a major negative impact on peatlands carbon stores and people in the SE Asia region. The next El Niño event is predicted within four years. The predicted changes to climate over the next 50 years as a result of increasing GHG emissions, including hotter temperatures and changes in rainfall patterns combined with land use change and deforestation, will lead to increased degradation of peatlands, increased emissions of GHGs and further acceleration of climate change.

The workshop proposed the following target :

All stakeholders (including government, non-government, research, private sector and local communities) should urgently work in partnership to prevent peatland fires and degradation. In addition, promote rehabilitation and sustainable use of peatlands in SE Asia to provide multiple benefits to the people in the region and safeguard the global environment.

The workshop recommended relevant stakeholders to:

Regional and global actions

- Expedite the implementation of the ASEAN Peatland Management Strategy and associated National Action Plans. These should be complemented by plans at the provincial and local level in regions with extensive peatlands.

- Strengthen policies and institutional arrangements for peatland management and strictly enforce policies and rules for the management and conservation of peatlands.
- Stop the further conversion and/or drainage of deep peat and peat domes and maintain and restore the hydrology of peatland systems to prevent fires, minimize GHG emissions, and maintain ecological services.
- Improve current forestry, agriculture and plantation management practices to ensure that they contribute to the sustainability of peatlands.
- Promote international cooperative studies to assess the role of peatlands in mitigating climate change and the potential future impacts of climate change and land use on the peatland carbon pool.
- Undertake an assessment of the vulnerability of peatlands to climate change and extreme events. Effectively disseminate the knowledge generated by the scientific community for use by decision makers and to support the assessment processes and later develop adaptation strategies to guide peatland managers, in particular plantation operators.
- Strengthen activities for monitoring changes in the status of tropical peatlands to guide wise management.

Riau Province

- Establish a Riau Peatland Management Partnership to bring together key stakeholders to work together to maintain and rehabilitate peatlands and promote sustainable use.
- Develop through a multistakeholder process, a masterplan for the future conservation and sustainable development of the Kampar Peninsular given its importance as one of the largest and currently relatively intact tropical peatlands in the world.
- Develop integrated management plans for each peatland to maintain the provision of ecosystem functions and services including carbon storage and water supply – as most major peatland ecosystems function as one hydrological unit but are administered by two or more District (Kabupaten) administrations and are managed by a range of agencies.
- Incorporate peatlands as a key part of integrated river basin management since peatlands in Riau form the largest stores of freshwater in the province and play a key role in regulating river flow and preventing saline intrusion and that peatland degradation will jeopardise future water supply.
- Support community-based initiatives for protection and sustainable use of peatlands in Riau as an incentive to maintain peatlands and associated ecosystem services.

Appendix 3: Proposed Contents of peer reviewed publication arising from the project

Vulnerability of Carbon Pools in Tropical Peatlands
ECOSYSTEMS
(Springer Journal)
Special Feature

Editors: Josep Canadell, Faizal Parish, Daniel Murdiyarso

1. **Global significance and vulnerability of carbon in tropical peatlands**
   Josep Canadell, Faizal Parish, Daniel Murdiyarso, Susan Page

2. **Extension and carbon content of tropical peatlands**
   Nyoman Suryadiputra Verhagen Jan, Bostang Radjagukguk, , Jian Li Asari Bin Hassan, Gusti Anshari et al.

3. **Land use/cover change in tropical peatlands: drivers, extension, C consequences, adaptation and mitigation**
   Daniel Murdiyarso, Kevin, Yumiko, Munoz, Arief, Zulfahmi, Nyoman, et al.

4. **The carbon balance of tropical peatlands** (minus fire emissions)
   Takashi Hirano, Jyrki Jauhiainen, Lulie Melling, Takashi Inoue, Takahashi, et al.

5. **Tropical Peatlands and Fire: drivers, extension and C emissions**
   Allan Spessa, Edvin Aldrian, Murphy, et al.

6. **Ecological restoration of tropical peatlands for reduced GHGs and biodiversity conservation**
   Susan Page et al.

7. **Future Trajectories: scenarios of land use, climate, C emissions, impacts**
   Aljosja Hooijer, David Hilbert, Wenhong Li, John McGregor, Faizal Paris, Pep Canadell, et al.

Appendix 4: Abstracts of papers presented at the Project workshop in Indonesia

GREENHOUSE GAS EMISSION FROM PEAT SOIL WITH DIFFERENT AGRICULTURAL PRACTICE

Abdul HADI[1)], Petrus LONDONG[1)], Mio MURAKAMI[2)] and Kazuyuki INUBUSHI[2)]

[1)]Division of Soil Science, Faculty of Agriculture, Lambung Mangkurat University, P.O. Box 1028 Banjarbaru (70714), E-mail: atakhadi@hotmail.com
[2)] Graduate School of Science and Technologi, Chiba University, 648 Matsudo, Japan

ABTRACT

The pressure on peatland, which is estimated to cover 240 million ha world over, ought to increase in future to produce more food or to serve changing life style. Due to high carbon and nitrogen contents coupled with human intervention, cultivated peatland are being considered as significant sources of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions (Hadi et al., 2005; Furukawa et al., 2005). The development of efficient soil management practices would minimize the emission of these gases from cultivated peat soil. This needs an understanding of the dynamics of these gases under a given agricultural practice.

Soil ameliorant and intermittent drainage are commonly practiced by farmer in many countries. Soil ameliorant can be a mineral soil, organic waste, or an agro-chemical and is needed to improve the physicochemical properties of peat soil (Kondoh, 1993; Widjaya-Adhi, 1978). Intermittent drainage can happen in the tidal swampy or in irrigated areas and is needed to remove hazardous organic compound and to increase the availability of some nutrients in rice rhizosphere (Radjagukguk, 1990). There are few reports on the effect of these two agricultural practices on the emissions of greenhouse gases (GHGs) from peatland.

To study the effect of soil ameliorant and intermittent drainage on emissions of N_2O and CH_4 from peat soil, two pot-experiments were carried out using Japanese peat soil. Izumi peat was used in the experiment I. Kuzyukuri sandy or Kashiwa andosol was incorporated into the peat as ameliorant. The emission of N2O and CH4 were measured on weekly basis. For the second experiment, Izumi peat was used. The intermittent drainage was performed by drying peat soil for 5 days interval during the flowering stage of rice growth. The emissions of N_2O and CH_4 were measured on weekly basis except in the period of intermittent drainage that was measured every 2 days.

To investigate effect of soil ameliorant on the CH_4, N_2O and CO_2 emissions from tropical peat soil cultivated to rice or corn, pot and lysimeter experiments were carried out using Indonesian peat soil. For pot experiment, peat was filled into 12 pots of 5 L volume. Cupper oxide (20 kg ha^{-1}), $ZnSO_4$ (20 kg ha^{-1}) or coal ash (20 kg ha^{-1}) were then incorporated either into the soil. Pots without soil ameliorant were also prepared as control. All treatments were replicated three times and arranged according to completely randomized experimental design in a green house. Gas samples were taken in monthly basis and analyzed for CH_4, CO_2 and N_2O. For the lysimeter experiment, 72 plots were prepared by constructing wooden boxes (180 cm length, 80 cm width and 30 cm height) and filling the boxes with peat soil. Treatments tested including chicken dung (0 ton ha^{-1}, 2 ton ha^{-1}, or 4 ton ha^{-1}) and effective microorganisms (0 L ha^{-1}, 5 L ha^{-1}, 10 L ha^{-1} or 15 L ha^{-1}). The plots ware arranged according to split plot design with 3 replications. Sweet corn seeds (*Zea mays* L. var *saccharata* Sturt) were planted at 60x20 cm spacing, 3 weeks after application of soil ameliorant and basal fertilizer. Gas samples were taken at harvest stage of corn and analyzed for CH_4 and CO_2.

The results showed that intermittent drainage significantly reduced the amount of CH_4 emission (Table 1). However, incorporation of mineral soil significantly increased the CH_4 emission from peat soil. There was no significant difference in amounts of CH_4 emission from peat soils dressed with sandy (17.4 mg C m^{-2} h^{-1}) or andosol (16.8 mg C m^{-2} h^{-1}); while that from peat alone (control) remained the lowest (8.9 mg C m^{-2} h^{-1}). Neither soil dressing nor intermittent drainage had any significant impact on N_2O emission. Soil Eh seemed to be the main factor controlling the sifting in CH_4 emission from peat soil (Figure 1).

Treatments	CH_4 (mg C m^{-2} h^{-1})	N_2O (mg C m^{-2} h^{-1})
Intermittently drainage	11.5[a]	0.42[a]
Continuously flooded	5.8[b]	0.38[a]

Table 1. Averaged CH_4 and N_2O emissions from peat soil as affected by intermittent drainage

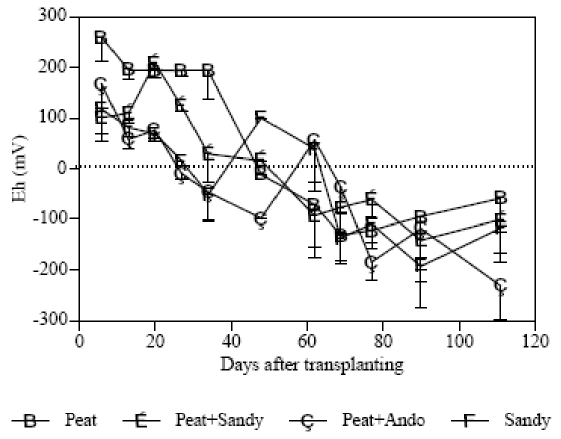


Figure 1. Changing in soil Eh as affected by soil ameliorants

There was no significant effect of coal ash, $ZnSO_4$ or CuO on emissions of GHGs from tropical peat soil cultivated to rice. The emissions ranged from 0.30 to 0.70 mg C m^{-2} h^{-1}, 0.01 to 0.21 mg N m^{-2} $h^{-1}$and 997 to 2360 mg C m^{-2} h^{-1} for CH_4, N_2O and CO_2, respectively. This was probably due to the negligible change in soil Eh upon the incorporation of these soil ameliorants (data not shown). Similarly, neither CH_4 emission nor CO_2 emission from the corn field was affected by soil ameliorants. The emissions of CH_4 ranged from 0.06 to 0.80 mg C m^{-2} h^{-1}, while the emissions of CO_2 ranged from 35.8 to 1,306.74 mg C m^{-2} h^{-1}. This indicates that the addition of soil ameliorants. Interaction of soil between soil type and chicken dung increase affected the corn yield, while effective microorganisms had no effect (Priyadi et al., 2005). This indicates that corn field on peat and alluvial soils can be incorporated with chicken dung to improve the yield without worrying the increase in gas emissions.

It can be concluded that intermittent drainage can be practiced, while the soil ameliorants can be or can not be practiced depends upon the Eh they affect.

Contribution to synthesis papers and the design of an integrative study:

Current study reviled that water regime plays a key role on the emissions of GHGs from peat soil, i.e., intermittent drainage is a promising technology to minimize or so called “mitigation option of” GHGs emissions from tropical peat soil. Therefore, it needs to be scale up to the farmer level. The intermittent drainage can occurred naturally in tidal area of coastal peat and in irrigated area. For future study, it might be important to elucidate the measure of and possible constrains in applying this option in the farmer level.

SATELLITE RADAR OBSERVATION OF TROPICAL PEAT SWAMP FOREST AS A TOOL FOR HYDROLOGICAL MODELLING AND ENVIRONMENTAL PROTECTION

Dirk H. Hoekman

Wageningen University
Dept. of Environmental Sciences, Sub-department of Water Resources,
Soil Physics, Ecohydrology and Groundwater Management Group
Nieuwe Kanaal 11, 6709 PA Wageningen, The Netherlands
tel:+31-317-482894, fax:+31-317-484885, email: Dirk.Hoekman@wur.nl

ABSTRACT

Radar observation
The use of spaceborne radar to map and monitor peat swamp forests has certain unique advantages. In the first place, observation by radar systems is unimpeded by cloud cover, which is an advantage over optical data in the humid tropics. In the second place, radar can penetrate vegetation cover to a certain extent, depending on wavelength. The JERS-1 and ALOS imaging radar (or SAR) systems use a relatively long wavelength (23.5 cm, or 1.275 GHz), also referred to as L-band. It allows observation of flooding under a closed forest canopy. Hence, in principle, seasonal flooding dynamics can be revealed well.

Mawas field station
To study peat swamp hydrology, ecology and radar wave interaction in a systematic way a dedicated research station has been established in the Mawas peat swamp forest conservation area, which is located some 80 km east of Palangkaraya, in the province Central Kalimantan and is managed by the Borneo Orangutan Survival Foundation. The main feature is a research bridge, 23 km in length, crossing an entire peat dome. Instruments placed along this bridge automatically measure rainfall and water level every hour. Field surveys have been made to characterise the vegetation structure variation along this bridge. Moreover, in December 2004, an airborne radar survey (the ESA INDREX-2 campaign) was carried out along this bridge to test a variety of advanced imaging radar techniques. The intention is to collect data over an extended period (i.e. 10 years) to develop hydrological modelling, examine relationships between hydrological, soil and vegetation characteristics, study carbon sequestration and to relate biomass and water (flooding) levels to L-band radar observations of the ALOS PALSAR instrument.

Discussion
Many of the tropical peat swamp forests in Borneo and Sumatra are seriously threatened by (illegal and legal) logging and conversion to plantations for the oil palm and pulp and paper industries. In all cases the hydrology is affected by excess drainage, leading to collapse of remaining forests, notably in dry years. Beyond a certain point the hydrological integrity of ombrogenous areas is lost, leading to an irreversible process of total collapse and the combustion and oxidation of the remaining thick peat layers. Unless rigorous measures are taken very soon, this most likely will lead to major negative effects on biodiversity and global climate.

More information is needed to support protection and restoration efforts. The availability of better vegetation and peat depth maps may be very useful. However, the most crucial factors may appear to be the knowledge on the hydrological functioning and the relationships between hydrological and ecological characteristics. These latter points are still poorly understood. Radar, unimpeded by cloud cover, can provide continuous observations which can be related to hydrological characteristics, may become a key instrument in future protection and restoration efforts. To achieve this, three types of activities will be undertaken. *These activities could contribute to synthesis papers and the design of an integrative study.*

(1) Analysis of historical JERS-1 SAR series. These often cover fairly pristine states. In combination with supporting satellite data, such as Landsat and SRTM elevation images, an assessment of the original hydrological behaviour may be made. Early disturbances, such as canals and forest collapses during the ENSO event, can be inventoried.
(2) Preparation for PALSAR data exploitation. PALSAR data are intended to be used to refine the knowledge of the peat forest areas, notably through the analysis of a series of 8 observations every 46 days (starting in 2006), which capture a full seasonal cycle. Continued observations

until 2010 may provide up-to-date information for many years for the whole area of Insular SE Asia.

(3) Studies along the research bridge in Mawas have been established to refine knowledge on physical behaviour and ecology. The water level and flooding measurements will yield important empirical data for the calibration of radar data interpretation algorithms for tropical peat swamp forests.

Exploitation of PALSAR time series to be collected by the ALOS satellite may provide significant support for peat land management, protection and restoration, such as described in the Ramsar “Guidelines for Global Action on Peatlands (GGAP)”. Moreover, it may significantly support other international treaties, such as CBD and Kyoto Protocol, and carbon cycle science.

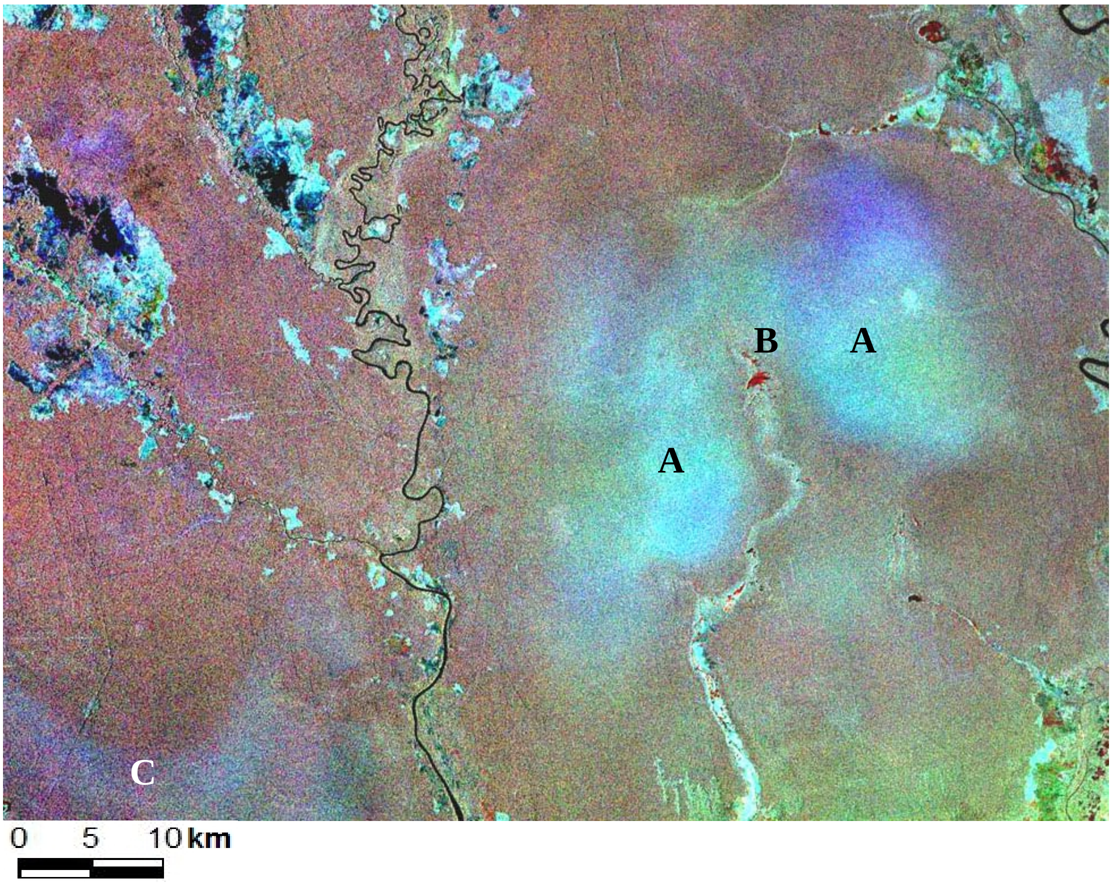


Figure. Temporal dynamics in flooding intensity can be related to the hydrology of ombrogenous peat swamp forests and, indirectly, to peat depth. The blue areas labelled as A are flooded parts of the relatively flat tops of a complex of two peat domes, with a river originating from a central depression (B). The feature labelled as C shows the relatively flat and wet fringe of a dry peat dome. Mawas area, Central Kalimantan; JERS-1 SAR multi-temporal composite image (Red 7 Sep 1994; Green 12 Jul 1995; Blue 4 Jan 1996).

CARBON BALANCE OF A TROPICAL PEAT SWAMP FOREST IN CENTRAL KALIMANTAN, INDONESIA

T. Hirano[1], H. Segah[1,2], S. Limin[2], T. June[3] and M. Osaki[1]
[1]*Graduate School of Agriculture, Hokkaido University, Sapporo, Japan*
[2]*University of Palangkaraya, Palangkaraya, Indonesia*
[3]*BIOTROP, Bogor, Indonesia*

ABSTRACT

Peatland existing in the tropics has accumulated a large amount of carbon as organic matter. Indonesia contains the largest area of tropical petland, and the petaland usually coexists with tropical peat swamp forests. Recently, however, deforestation and drainage are in progress on a large scale owing to a growing demand for timber and farmlands. In addition, the ENSO drought and its consequent large-scale fires are accelerating the devastation of the peatland. The devastation enhances the decomposition of organic matter stored in peatland, and consequently increases carbon release to the atmosphere as CO_2. This suggests that tropical peatland will be a major CO_2 source in the near future. To evaluate the CO_2 balance of tropical peatland, we have measured CO_2 flux above a tropical peat swamp forest remaining in Area B of the Mega Rice Project near Palangkaraya, Central Kalimantan, Indonesia since November 2001.

The forest is located on flat peatland between a river and channel. Water table in the forest was zonally reduced near the channel. A tower of 50 m height was constructed about 300 m inside from the northeast corner of the forest (2º 20' 41.6" S, 114º 2' 11.3" E) (Fig. 1, KF). Dominant tree species of the forest are *Combretocarpus rotundatus*, *Cratoxylum arborescens*, *Buchanania sessifolia* and *Tetrameristra glabra* and rich shrubs grow in the trunk space. The height of the forest canopy is about 26 m. Predominant wind direction was the south (SE-SW). Fetch was longer than 1 km for the southern wind. During the dry season of 2002, between mid-August and late October, peatland fires occurred in large areas around Palangkaraya because of the ENSO drought, whereas the forest did not burn. In 2004, we established new sites in a burnt area near KF site (KB) and a undrained natural peat swamp forest (SF). At both of the sites, CO_2 flux has been measured.

CO_2 and energy fluxes have been measured at 41.7 m by the eddy covariance technique with a sonic anemometer-thermometer (CSAT3, CSI) and an open-path CO_2 analyzer (LI7500, Licor) facing the south. Sensor signals were recorded with a data logger (8421, HIOKI) at 10 Hz. In addition, CO_2 concentrations have been measured at six heights below the flux measuring height with a closed-path CO_2 analyzer (LI820, Licor) to calculate CO_2 storage flux (F_s). Hourly mean fluxes were calculated from the data according to the following procedures: 1) removal of noise spikes, 2) planar fit rotation, 3) covariance calculation using block average, 4) WPL correction. From CO_2 flux (F_c) and F_s, net ecosystem CO_2 exchange (NEE) was calculated (NEE = F_c + F_s). Data quality was checked by wind direction and steady state tests. In addition, a friction velocity (u*) threshold of 0.17 m s^{-1} was applied for nighttime. Gaps of missing data were filled using the look-up table method. Ecosystem respiration (RE) or nighttime NEE was estimated from soil moisture, and daytime NEE was estimated form photosynthetic photon flux density (PPFD) and vapor pressure deficit (VPD); gross primary production (GPP) was estimated by subtracting RE from NEE.

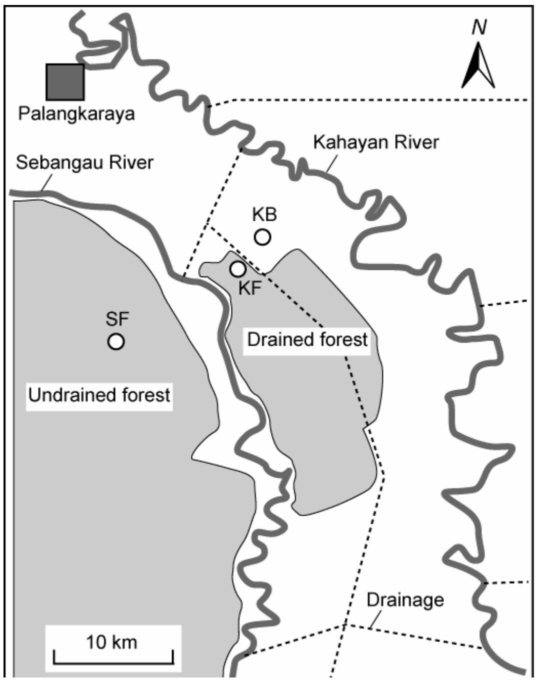


Fig.1 Map of study area.

In this area, the dry season began in May and lasted until October, judging from monthly precipitation of 100 mm. CO_2 fluxes showed seasonal variations. Typically GPP continued to become more negative from the mid rainy season until the mid dry season, and rapidly became more positive in the late dry season. On the other hand, RE continued to increase through the dry season. As a result, NEE was smallest in the mid dry season at around zero and largest in the late dry season. In total, GPP and RE were significantly more negative and positive, respectively, in the dry season than the rainy season. However, NEE showed no significant difference between two seasons. These seasonal variations of CO_2 fluxes were caused by those of environmental factors including PPFD, vapor pressure deficit (VPD) and water table and tree phenology. During the dry season, high PPFD enhanced GPP until July or August, whereas high VPD depressed it in September and October. Low water table, which reflected on low soil moisture, enhanced RE through peat decomposition because the aerobic layer of peat increased; the negative relationship between RE and soil moisture is a distinctive feature at peatland.

The annual sums of NEE were 609, 368 and 346 gC m^{-2} y^{-1} in 2002, 2003 and 2004, respectively. This forest worked as a net source of CO_2 at an intensity of 441±146 gC m^{-2} y^{-1} for the atmosphere from 2002 through 2004. Although uncertainty due to gap-filling was large, the source intensity was largest in 2002, an ENSO year; this was probably caused by drought and low PPFD, which was caused by dense smoke emitted through large-scale fires.

Acknowledgements
This work was supported by supported by JSPS Core University Program and the Grant-in-Aid for Scientific Research (Nos.13375011 and 15255001) from the Japanese Ministry of Education, Culture, Sports, Science and Technology

Data for synthesis papers:

1. Half-hourly meteorological data measured on the KF tower in a drained forest (Fig. 1) from mid-July 2001 to the end of 2004, including air temperature, humidity, radiation, wind, precipitation, soil moisture and soil temperature.
2. Daily NEE after gap-filling for the drained forest in 2002, 2003 and 2004.

PRECISE MEASUREMENTS OF PEATLAND TOPOGRAPHY AND TREE/CANOPY HEIGHT WITH A HIGH-RESOLUTION AIRBORNE LASER-SCANNER TO CALCULATE CARBON- AND BIO-MASS

Dr. H.-D.V. Boehm
Kalteng Consultants, Kirchstockacherweg 2, D-85635 Hoehenkirchen, Germany
Email: viktorboehm@t-online.de, www.rhc.at/kalteng
and
Jalan Tjilik Riwut km36, Rungan-Sari No.33, Palangkaraya, 73225 Kalimantan, Indonesia
presented at Global Carbon Science-Workshop, Pekanbaru, Indonesia, 24-26.Jan 2006

ABSTRACT

High-resolution airborne Laser-Scanners installed in helicopters or fixed wings have increased the z-range-resolution (height) measurement to a value of **better then 0.15m** over the last ten years. With these precise, dense and geo-referenced 3D-measurements (x, y and z) demanding applications are now possible, such as:

- forest inventory and bio-mass monitoring of PSF; finding illegal logging activities
- flood plain mapping and costal monitoring
- hydrological simulations and hydrological models
- inventory of precise topographic maps and land use mapping
- environmental protection, disaster management, erosion measurements
- urban, pipelines and wireless network planning and city models
- power line and power pole mapping and forest growth near power lines
- monitoring of disposals and mines
- archaeology and change detection
- calibration of airborne or satellite SAR products

After processing laser row data with intensity information a high-quality Digital Surface Model (DSM) and a high-quality Digital Terrain Model (DTM) can be derived as standard product. The digital surface model uses the first echo (FE) of the laser beam, the digital terrain model its last echo (LE). Other products derived from this are difference models, TINs (Triangular Information), break lines and contours. The x-, y-resolution grid can be of the order 0.5m or 1m or 3m or 5m with 30 to 3 points/m². This laser-scanner can measure the height of peat swamp forest (PSF) at the canopy area with the first echo and peat surface and peat dome with the last echo. Tree height and Bio-Mass of PSF are obtained by subtracting the two echoes and multication of the area. With additional peat depth drillings at selected way-points, this method can evaluate the amount of stored Carbon in peatland better than used any other. Monitoring of illegal logging is easily possible.

High quality hydrological models can be analysed and thus offer a better understanding of peatlands. In combination with airborne or satellite SAR-systems (synthetic aperture radar), that are able to monitor large land areas, the airborne laser-scanner can calibrate SAR-data.

Laser-scanner technology has come out of the research phase and is now fully mature. In combination with line scanner, true ortho images (RGB, CIR) can be produced. Most laser-scanners have an inertial navigation system (INS) including a roll stabilisation and a differential-global positioning system (D-GPS), to achieve a geo-referenced product, which can be processed and stored in a Geographical Information System (GIS). Helicopters or small aircrafts equipped with laser-scanner are handled easily by one pilot and one operator, travelling at a speed of approx. 60m/s at an altitude of approx. 800m. Analysing the data can be done by skilled personnel or the operator with the help of available software. The equipment requires little maintenance. For reliable data, the laser beam should hit the canopy with an angle of incidence as close to normal as possible to achieve a good last echo from the ground. When clouds or haze are between the laser-scanner and the ground, the equipment cannot be used.

The wavelengths of laser-scanners are in the near infrared band between 1µm and 1.5µm. Some laser-products are eye-safe, others only in a higher flight-path at 800m. The laser-beam divergence has mostly a value of 1mrad.

Three companies, who offer flight services with Laser Scanners and providing the DSM- and DTM-products have been contacted and compared:

- Swissphoto (Switzerland), - Terra Digital (Germany) and - TopoSys (Germany).

Three Laser Scanner devices and their manufacturers are:
- ALTM 3100 from Optech, Canada, with a rotating mirror scanner;
- ALS 50 from Leica, Switzerland, with an oscillating mirror scanner;
- Falcon II/III from TopoSys, Germany, with a 128/300 fiber scanner; The measurement rate is 83kHz/125KHz; calibration of the scanner is required only once.

All of laser-scanners have advantages and disadvantages concerning technical parameters and operational and commercial aspects, but all have the advantage of cost efficient acquisition of precise laser and image data at the same time with 3 to 6 €/ha depending on laser-pixels/m².

Courtesy for information by Swissphoto, Terra Digital and TopoSys.

Keywords: Airborne Laser-Scanner, DSM, DTM, geo-referenced 3D-measurements + GIS, Peatland, Peat dome, Peat Swamp Forest, canopy, carbon, tree height, biomass, topographic maps

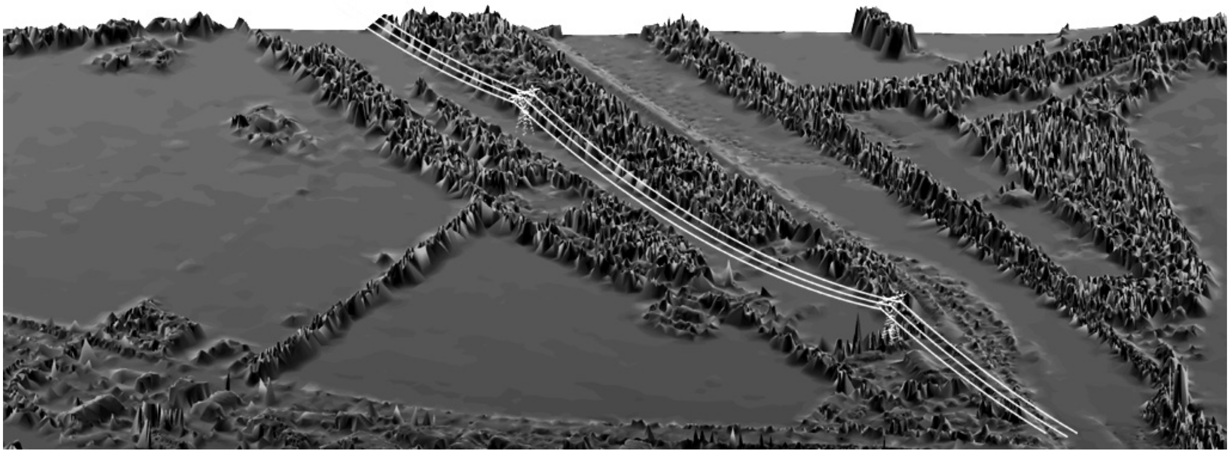


Fig.1: Digital Surface Model in perspective view, not coloured (courtesy Swissphoto)

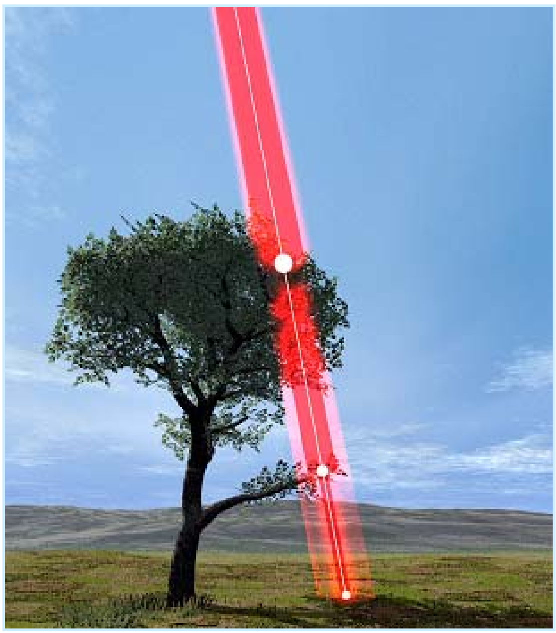


Fig.2: DSM from airport Lisbon (courtesy TopoSys)

Fig.3: Tree height measurement with first, medium and last laser echo (courtesy Swissphoto)

Fig. 3a: Digital Surface Model (DSM) derived from Laser Scanner row data with forests

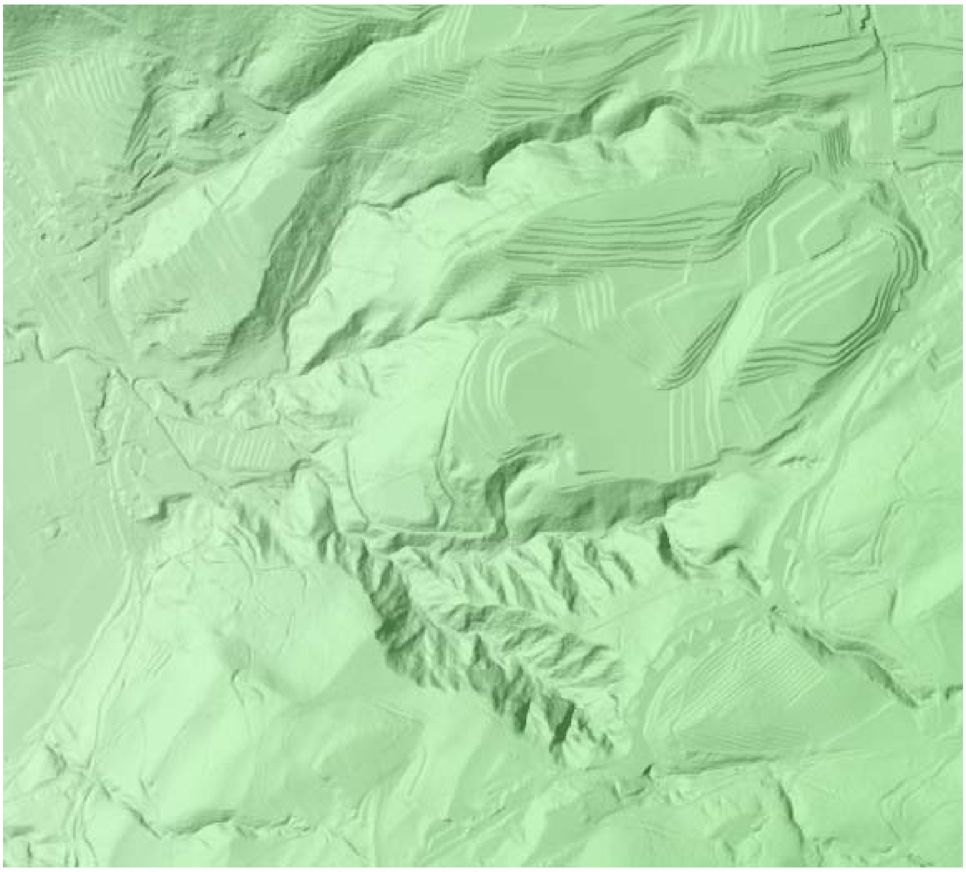


Fig. 3b: Digital Terrain Model (DTM) derived from Laser Scanner row data showing the relief and topography (courtesy Swissphoto)

GREENHOUSE GASES (CH_4, N_2O) STUDIES: PEAT SWAMP IN NARATHIWAT, THAILAND

Proespichaya Kanatharana[1*], Narin Boontanon[1], Danai Tipmanee[1],
Shingo Ueda[2] and Eitaro Wada[3]

[1] Analytical and Environmental Chemistry/Trace Analysis Research Unit (AEC/TA-RU), Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand
[2] Nihon University, Japan
[3] Ecosystem Change Research Program, of the Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan

ABSTRACT

Narathiwat Province was chosen as the study site because of it abundance of peat swamp forest. The study sites has extremely high rainfalls in November - December and dry season in January – April (rainfalls below 100 mm.). The flux of CH_4 and N_2O were studied by chamber method and quantified and qualified by Gas Chromatographic Technique with Flame Ionization Detector (FID) and Electron Capture Detector (ECD).

The sample were monthly collected from 3 main sites i.e. Bang Nara River, To Deang Swamp and Bacho Swamp during 1993-1994. The results shown that the fluxes of CH_4 were 4.80 ±1.95 mg $C(CH_4)/m^2$/hr, 3.16 ± 1.58 mg $C(CH_4)/m^2$/hr and 1.95 ± 1.45 mg $C(CH_4)/m^2$/hr. respectively. The N_2O fluxes were 17.5 ±8.8 g N/m^2/hr, -2.0 ±6.0 g N/m^2/hr and –0.5 ± 3.8 g N/m^2/hr. respectively.

Aljosja Hooijer

ABSTRACT

PEAT CO2: Peatland CO2 Emission Assessment Tool The fact that drainage of peatlands is a significant source of CO2 emissions is undisputed in scientific circles (although some discussion exists on the exact rates) but generally unknown. The issue is therefore not (or hardly) weigthed in peatland management planning; the fact that palm oil produced in drained peatlands is accepted as a biofuel (while some 20 tonnes of CO2 are emitted for production of 1 tonne of oil) serves as an example of this lack of awareness. To help change this, the PEAT CO2 initiative (supported by Delft Hydraulics, Wetlands International and ALTERRA) has developed a rapid assessment method and a 'demonstration tool' (at the prototype stage) that aims to present the key facts in a simple and transparant way to decision makers and the media. The present version of the Tool presents calculated CO2 emissions on a 5*5km gridded map of the world; a tentative calculation result is that global emissions from oxidation amount to 690 Mt/y, over 10% of global emissions from fossil fuel burning. The short-term goal is to involve the wider science community in completing the tool, which may also act as an open platform for bringing together the best and latest knowledge available. The next goal is to disseminate the tool, supporting initiatives to get CO2 emissions from peat management recognized in carbon sequestration decision making, making available a new funding source for conservation and mitigated management of peatlands. A further goal is to develop the PEAT CO2 platform into a management support tool for specific managed peatland areas, taking into account basic hydrological and ecological principles. A trial version of such a tool was succesfully applied for an impact assessment of drainage plans in the Kampar Peninsula (Sumatra).

IMPACTS OF RECLAMATION AND EMISSION OF CO_2 FROM CROPLANDS

Nyahu Rumbang, Bostang Radjagukguk and Djoko Prajitno
School of Postgraduate Studies, Gadjah Mada University, Yogyakarta 55281
Indonesia. E-mail: bradjagukguk@yahoo.com

ABSTRACT

The major impacts of land reclamation for agriculture on the surrounding ecosystems are caused by low quality of drainage water flowing out of the reclaimed area, by alteration to local and regional hydrology due to construction of drainage canals, and by uncontrolled burning. These impacts can be minimized by careful designing of canal system, by controlling burning, and by proper management of amendments and fertilizers in the cultivated area.

Once the natural peatland is developed, its carbon storage function will change, and peat decomposition by microorganisms is accelerated releasing CO_2 as one of the major end products. Study of Vasander and Jauhiainen (2001) showed that CO_2 emission from pristine peat swamp forests varied from 276 to 682 $mg.m^{-2}.h^{-1}$ at water levels +20 cm and – 35 cm from the surface. At most water levels studied, CO_2 emission reached >600 $mg.m^{-2}.h^{-1}$. Study of Barchia and Sabiham (2002) showed that increasing intensity of soil tillage without amelioration increased CO_2 emission by about 80-90 $mg.m^{-2}.h^{-1}$. In Malaysia, CO_2 emission from maize and oil palm cultivated peatlands varied from 326 to 418 $mg.m^{-2}.h^{-1}$ (Jauhiainen *et al.*, 2002).

Results of CO_2 emission measurements in our study showed that average emission in the annual crops site ranged from 350 to 400 $mg.m^{-2}.h^{-1}$ (Figure 1). These were in the same order of magnitude as those previously reported for cultivated peatlands elsewhere. Hence, it could be concluded that CO_2 emission rate would not increase drastically with peatland reclamation and cultivation unless uncontrolled burning is practised.

References

Barchia, F. and Sabiham, S. (2002). Release of phenolic acid and carbon from rice fields in Central Kalimantan peatland. In *Proceedings of Jakarta Symposium on Peatland for People – Natural Resource Functions and Sustainable Management*. J.O. Rieley and S.E. Page (editors), pp. 75-80.

Jauhiainen, J., Vasander, H., Heikkinen, J. and Martikainen, P. (2002). Carbon fluxes in pristine and developed Central Kalimantan peatland. In *Proceedings of Jakarta Symposium on Peatland for People – Natural Resource Functions and Sustainable Management.* J.O. Rieley and S.E. Page (editors), pp. 207-210.

Vasander, H. and Jauhiainen, J. (2001). Measuring CO_2 emissions in tropical peatlands. *International J. for the Management of Tropical Peatlands* 1: 16-19.

SOIL CO_2 FLUX FROM THREE ECOSYSTEMS IN TROPICAL PEATLAND OF SARAWAK, MALAYSIA

Lulie Melling[1)], Ryusuke Hatano[2)] and Kah Joo Goh[3)]

[1]Department of Agriculture, Jalan Badruddin, 93400, Kuching, Sarawak, Malaysia
[2]Graduate School of Agriculture, Hokkaido University, Sapporo, 060-8589 Japan,
[3]Advanced Agriecological Research Sdn Bhd, Locked Bag 212, Sg. Buloh P.O., 47000, Sg. Buloh, Selangor, Malaysia

SUMMARY

The atmospheric concentrations of carbon dioxide (CO_2) has steadily increased since the period of the industrial revolution at the rate of 0.4%. As of today, the atmospheric concentration of atmospheric carbon is well documented, but the magnitude of soil CO_2 flux from individual ecosystems is still lacking especially tropical peatland. Tropical peatland plays an important role in the global carbon cycle as carbon stores. The tropical peatland constitutes over 8 % (33-49 Mha) of the global peatland area of 386-409 Mha. However, it may store more than 70 Gt or up to 20 % of global peatland carbon.

The largest area of tropical peatlands is in Southeast Asia, largely found in Indonesia and Malaysia. There is also an on-going extensive conversion of tropical peatland forest to sago and oil palm plantations in Malaysia and Indonesia, and the magnitude of the soil CO_2 flux from such ecosystems is still unreported. This is indeed one of the main reason why estimates of the source and sink strength for soil CO_2 flux is still highly uncertain. There is a great need to know the source and sink strength of the soil CO_2 flux and the major factors controlling them to determine their contribution to the global C emission inventories. A one-year data set of the soil CO_2 flux was acquired from three ecosystems, namely mixed peat swamp forest, sago and oil palm on tropical peatland. Soil CO_2 flux were measured by using a closed-chamber method. The three studied sites were all located within a 10 km radius of the same peat swamp basin in the Mukah Division of Sarawak, Malaysia. Measurements were made over a year at monthly intervals from August 2002 to July 2003.

To understand the effect of land use change on the environmental factors, we had used the principal component analysis (PCA). The PCA had successfully identified the conversion effect of primary forest to oil palm and sago plantations. The conversion had caused a change in the microclimate whereby the relative humidity declined while air and soil temperatures increased significantly for both sago and oil palm ecosystems compared with forest ecosystem. This maybe attributed to the small canopies of both sago and oil palm ecosystems being young perennial crops, which had not closed. The partial exposure of the peat surface resulted in higher fluctuations in air and soil temperature. Cultivation of sago on peat had also modified the moisture status to more anaerobic condition due to higher water table and % of water filled pore space (WFPS).

The annual soil CO_2 flux was highest in the forest ecosystem, with an estimated production of 2.1 kg C m^{-2} yr^{-1} followed by oil palm at 1.5 kg C m^{-1} yr^{-1} and sago at 1.1 kg C m^{-1} yr^{-1}. This study showed that cultivation of peat soils to oil palm and sago reduced the soil CO_2 flux by 29 and 48% respectively compared with primary peat forest. The soil CO_2 flux of forest was among the highest reported in the literature, while those from oil palm and sago were similar to other common crops on peat such as paddy in Borneo and grassland in the Amazon. The results of tree regression analysis which is a method that divides the gas fluxes into a hierarchial sequence of groups based on the predictive power of the environmental factors, showed that the dominant environmental variables for explaining soil CO_2 flux were relative humidity for forest, soil temperature at 5 cm for sago and WFPS for oil palm ecosystems. This clearly indicates that changes of microclimate and soil environment associated with land use change strongly influences soil CO_2 flux from tropical peatland.

This study revealed that the impact of land use change in tropical peatland on soil CO2 flux was not as great as that reported in the IPCC. This also suggests that the conversion of tropical peat swamp forest to agricultural lands significantly affect the soil C fluxes in tropical peatland. Thus, the types of ecosystems should be taken into consideration when estimating soil CO2 flux from tropical peatlands. However, in order to evaluate whether tropical peatland ecosystems acts as sinks or sources of CO_2, further work to estimate net primary production is required.

LINKING MITIGATION AND ADAPTATION TO CLIMATE CHANGE: A SEARCH FOR FOREST AND LAND-USE POLICY OPTIONS

Daniel Murdiyarso

Center for International Forestry Research
Jl. CIFOR, Situgede, Bogor, 16680, Indonesia
d.murdiyarso@cgiar.org

ABSTRACT

Climate change and variability including extreme events such El Nino or La Nina could respectively enhance or diminish the spread and severity of fire disturbance regimes. In the past two decades fire becomes more important element in the earth system linking atmosphere and terrestrial ecosystems by which human interacts through land management land-use decisions.

Mitigating climate change through land-use policies has been widely accepted by public and private sectors. Capacity and awareness building for fire fighting have also been largely established. However, no effort has been made to link them. Meanwhile, it is not common to address the impacts of climate change on various development sectors including land and forest resources and their vulnerability, which could potentially adapt to fire disturbance regimes. It means that climate change adaptation strategies could offer adaptation strategies for fire disturbance regimes.

The challenges remain huge at local and national levels. Command and control system may need some adjustments by involving as much participation as possible. The roles of local and national governments in facilitating such participation are discussed in the light of global concerns. Mitigation options will be discussed as entry point to undertake the assessment of forest ecosystem vulnerability.

Keywords: policy responses, fire and emission mitigation, vulnerability assessment, climate change, adaptation strategies

MODELLING PEATLANDS AS DYNAMICAL SYSTEMS

David W. Hilbert
CSIRO Tropical Forest Research Centre
P.O. Box 780
Atherton, Qld. 4883
Australia

ABSTRACT

An understanding of the general dynamics of peatland growth is necessary in order to predict the effects of climate variability and change on their development and potential carbon storage, as well as to assess the implications of direct human activities such as draining and mining and to interpret their stratigraphy. The dynamical systems approach is complimentary to the more mechanistic simulation approaches and can provide insights that may not be apparent from the more complex models.

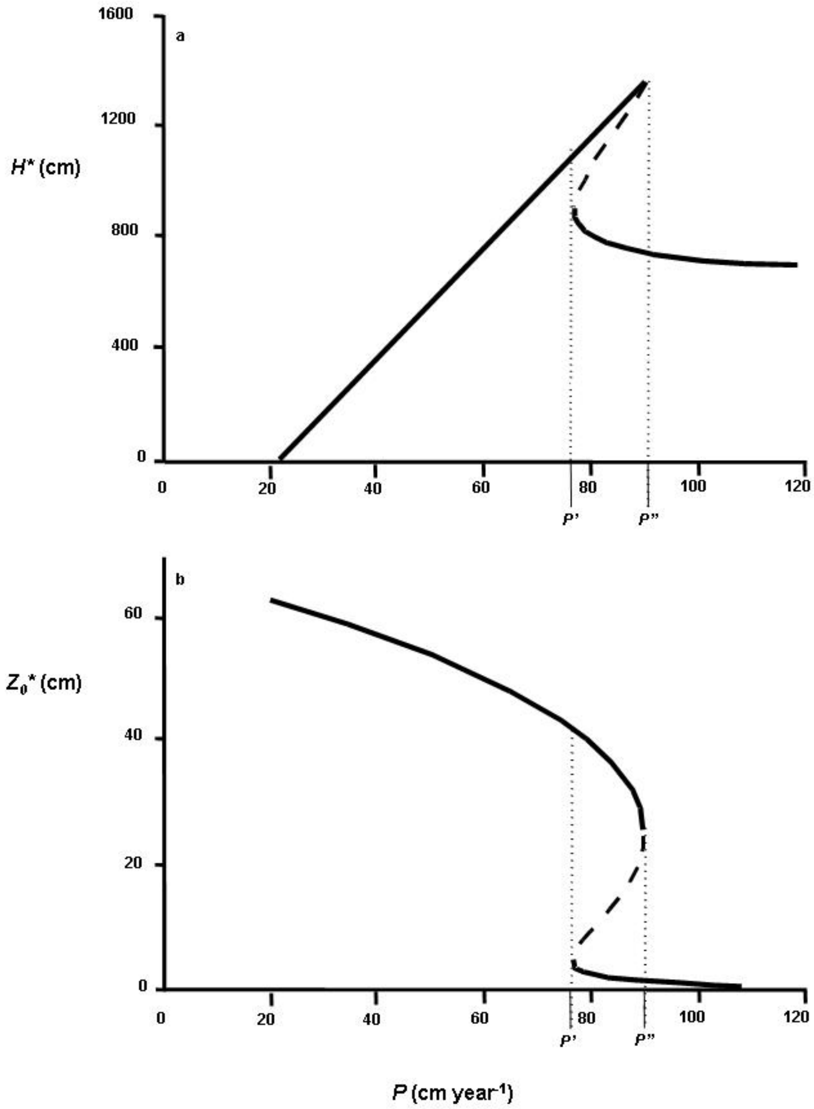
Conceptually, there are two broad views of peatland growth: 1) control by external factors such as climate and local basin hydrology (the allogenic model) and 2) control by internal factors (the autogenic model). Generally, the mathematical models have stressed autogenic mechanisms responsible for peatland dynamics. Almquist-Jacobson and Foster (1995) discussed a "mixed" model where both external climate and internal hydrology are considered simultaneously. However, this largely conceptual model does not represent dynamics mathematically.

Hilbert et al. (2000) developed a mathematical, “mixed” model for the dynamics of peat growth where depth to the water table is a dynamic variable with a nonlinear relationship between peat production and water table depth. They used a dynamcal systems approach to analyse the dynamics of the model and investigate the responses to altered precipitation regimes such as might occur with climate variability and change. The objective was to represent and analyse the consequences of simple but realistic assumptions for the long-term dynamics of peatlands.

The model consists of two coupled, nonlinear differential equations representing change in depth of peat and depth to the water table. The model provides an integrated view of how peatlands function over long time-scales by focusing on the nonlinear interactions among peat production, decomposition and hydrology.

Analysis of the model shows that equilibrium peat accumulation and water table depth depend on the net water input to the peatland (see figure below). In drier sites, peatlands with relatively deep water tables develop and the equilibrium peat depth increases with increasing water input. In very wet conditions, peatlands have water tables near the surface, peat accumulation is limited by low production rates and equilibrium peat depth is lower than is possible in comparatively drier sites. Over a range of intermediate water balances, there are two simultaneous equilibrium states where deep, dry peatlands and shallower, wet peatlands can both occur. This sensitivity to water balance suggests that small changes in precipitation regime, such as are expected with climate variability and change, could rapidly convert peatlands that are now in equilibrium into either sources or sinks of carbon.

The possibility that some peatlands in sites with particular, local water balances may have multiple attractors is important, both conceptually and practically. Because of this, while peat accumulation and decay is invariably a slow process, peatlands may be capable of rapid shifts from stocking to exporting carbon or vice versa. The implications of this for the global carbon balance are potentially significant given the large mass of carbon stocked globally in peat.



Plots of equilibrium height (H^*) and water table depth (Z_0^*) as affected by increasing water input through precipitation. When precipitation is relatively low (less than *P'*) there is one possible equilibrium for each value of *P* and the water table is relatively deep. For precipitation between *P'* and *P''* there are two possible stable equilibria separated by an unstable turning point (dashed parts of the curves). One of the two is comparatively deep and dry while the other is shallower and the water table is near the surface. Above *P''* there is again a single possible equilibrium for each *P* corresponding to the second of the two equilibria.

Hilbert, **D.W.**, N. Roulet and T. Moore. 2000. Modelling and analysis of peatlands as dynamical systems. *Journal of Ecology* 88: 230-242.

MODELING REGIONAL SMOKE HAZE DISTRIBUTION DUE TO PEAT AND VEGETATION FIRE EMISSIONS THE INDONESIAN SMOKE INDUCED BY DROUGHT EPISODE (INSIDE) PROJECT

Edvin Aldrian[1], Angelika Heil[2] and Baerbel Langmann[2]
[1]Agency for the Assessment and Application of Technology, BPPT, Jl MH Thamrin no 8 Jakarta 10340
[2]Max Planck Insitut fuer Meteorologie, Bundesstrasse 53, D-20146 Hamburg, Germany

EXTENDED ABSTRACT

Pressure on Indonesian forest fire management has increased since the last three decades. The problem has affecting many aspects of human lives such as transportation, air quality, public health, degrading environment and high political tension due to trans-boundary haze problem. In recent years, fire and smoke haze occurrence increased in Indonesia by intentionally set land clearing fires, higher fire susceptibility of disturbed forests and prolonged droughts coupled with El Niño. Particularly fires in drained peat swamps release huge amounts of emissions and are difficult to extinguish.

The INSIDE project aims to determine the amount and distribution of smoke haze in Indonesia and the adjacent countries generated from vegetation and peat fires, and the related implications for human health (e.g. respiratory diseases) and climate. The project provides, optimizes and applies a regional atmosphere-chemistry model for Southeast Asia. The INSIDE project uses the Max Planck Institute Regional Climate Model with a Tracer Extension (REMOTE). This model includes an estimate of the gaseous and particulate matter emission from vegetation and peat fires in Indonesia.

Numerical modelling of fire-related smoke-haze episodes in South-East Asia is important for both prediction and assessment of atmospheric impacts, especially when observational data are fragmentary, as is the situation in Indonesia. This work describes the dispersion of smoke particles emitted during the 1997 Indonesian fires modelled. We established a new fire emission inventory for July to December 1997 and continue to set up a longer term inventory. In this study we performed several scenarios in relation to peat land and meteorological importance, sea surface and ocean to air sea interactions. Utilising different scenarios, we studied the variable atmospheric impacts of surface vegetation fires and peat soil fires separately and also investigate the sensitivity of smoke-haze dispersion to the different meteorological conditions of an El Niño and a normal year. Local Sea Surface Temperature (SST) is another factor driving rainfall variability in Indonesia; therefore coupled atmosphere-ocean modeling with tracer extension will be carried out as well. We found out that even though fires were produced by human interferences, there is a strong correlation between fire in Sumatra and Borneo with climate activity over the Pacific. Furthermore, the use of a climate model allows us to study a regional wide impact of deforestation or land cover change to the meteorological condition. Thus we set up another experiment with two different land cover map before and after the large fire of 1997/1998. Using different meteorological condition we studied the distribution of smoke fire especially from peat lands of Sumatra, Borneo and West Papua and found the importance of peat land source in exaggerating the smoke haze distribution up to 8 times. Further experiment with future projection of climate change scenarios by nesting into this regional climate model is also foreseen. We will present some results of those scenarios during the ongoing INSIDE project.

Fire emission

We include emissions from subsurface fires in organic peat soils, which we calculate separately from the surface fire emissions. Estimates of the areas covered by peatland in Indonesia are highly uncertain. We derived the distribution of peat soils from areas designated as reference soil group histosol (HS) in the WRB (World Reference Base) Map of World Soil Resources (FAO/AGL 2003, available at http://www.fao.org/ag/agl/agll/wrb/soilres.stm). The total area of soils classified as reference soil group histosol (HS) in the inventory area is 436,000 km^2. The reference soil group histosol (HS) mapped in the inventory area using the WRB system. To account for this overestimation, we assume that 50% of the HS mapped is peat, resulting in a total peat soil area of 218,000 km^2, of which 30% is on Sumatra/Peninsular Malaysia, 34% on Borneo and 36 % on Irian Jaya. In this study, we use the area burned estimate of Tacconi (2003) and redistribute this area estimate in space and time using fire count data retrieved from the ATSR (Along Track Scanning Radiometer).

The so-called ‘hotspot’ or fire count data can provide information on the spatial and temporal occurrence of an active fire event, but not on the area burned within an individual fire count pixel (Malingreau 1990).

We use ATSR nighttime data from the ATSR World Fire Atlas (Arino et al. 1999) and aggregate them into 0.5*0.5 degree cells on a weekly basis. The ATSR thermal 3.7µm channel detects active fires through the induced changes in earth's radiative temperature using two algorithms. We used the low temperature threshold Algorithm 2 data (above 308 Kelvin) in our study because of the resulting enhanced sensitivity to also capture smouldering fires (e.g. peat fires) since these fires produce much lower temperatures then flaming fires (Malingreau 1990). ATSR data show a high correlation with burn scar area maps (R= 0.82 for Algorithm 2), albeit largely but consistently under-representing the number of active fires in Indonesia. Figure 2 a) shows the distribution of ATSR Algorithm 2 fire counts as number per model grid cell from July - December 1997 (39240 counts) and resulted in a mean area burned of 2.98 km2 per fire count. We scaled them to 2.25, 2.85 and 4.5 km2 burned per fire count for the fuel classes forest and peat soil, fragmented forest/plantation, and agriculture/grassland/savannah, respectively.

Data and Model setup

REMO (Regional Model) has been developed from the regional three dimensional weather forecast system EM/DM of the German Weather Service (Majewski, 1991). It includes the description of physical atmospheric processes based on the global atmosphere general circulation model ECHAM-4 (Roeckner et al., 1996). The standard horizontal resolution of the model is 0.5 degree, however. The REMO model was applied with a hybrid system of p and using 20 levels of vertical coordinates hydrostatically of increasing thickness between the Earth's surface and the 10 hPa pressure level using terrain following hybrid pressure-sigma coordinates. The present study model domain is bounded within 19S – 8N and 91E – 141E (around 18 million km^2). With a grid cell resolution of 0.5 degree will have a 101 and 55 grid points longitudinal and latitudinal, respectively. Vertical discretization follows Simmons and Burridge (1981). The time discretization uses a semi-implicit leapfrog scheme and the advection scheme is semi langrangian. The lateral boundary uses the method of Davies (1976), where the boundary zones extend to 8 grid rows. The grid scale precipitation is based on the solution of budget equations with the bulk schemes from Kessler (1969) and the sub grid scale precipitation processes follow Tiedtke (1989), which employs three types of convections: the penetrative, shallow and mid-level convections. Evaporation rate of the precipitation is computed according to Kessler (1969). Previous studies with the REMO atmosphere-chemistry model (e.g. Chevillard et al. 2002, Langmann et al. 1998, 2003, Langmann and Heil 2004) give confidence in the ability of the model to reproduce the physicochemical state of the atmosphere. Aldrian et al. (2004) and Aldrian et al. (2005) validated REMO performance in simulating the Indonesian rainfall and found good agreement between simulated and observed rainfall variability from rain gauges all over the region, particularly over Sumatra and Kalimantan.

A basic tracer transport and deposition module is included in the REMO model (Langmann, 2000), which is developed into REMO with Tracer Extension (REMOTE). Previous studies with the REMOTE atmosphere-chemistry model have been evaluated extensively and give confidence in the ability of the model to reproduce the physico-chemical state of the atmosphere. These applications cover studies of photochemical smog episodes over Europe (e.g. Langmann et al., 2003), investigations of the distribution and radiative forcing of sulfate aerosols over Europe (Langmann et al., 1998) and the Arctic region, CO_2 and R_n fluxes and distributions over Euro-Siberia (Chevillard et al., 2002) and also the fate of water isotopes in the atmosphere (Sturm et al., 2003).

Results

Fires in peat soil contribute 87.6% (47.3 Tg) to the total PM10 emissions although it is only 12.4% for fires in surface vegetation, although the area of surface vegetation is 4.2 times larger than the area of peat soil burned. Total C released from burning surface vegetation and peat soil in the second half of 1997 is estimated to be 1098 Tg C.The study illustrates the dominant role of peat fire emissions in creating severe transboundary air pollution episodes. Prevention of fires in peat areas is therefore of major importance. During El Niño years, the risk of large-scale, sustained peat fires is much higher because the areas that experience abnormal dryness in Sumatra and Kalimantan contain exceptionally large portions of peat soil.

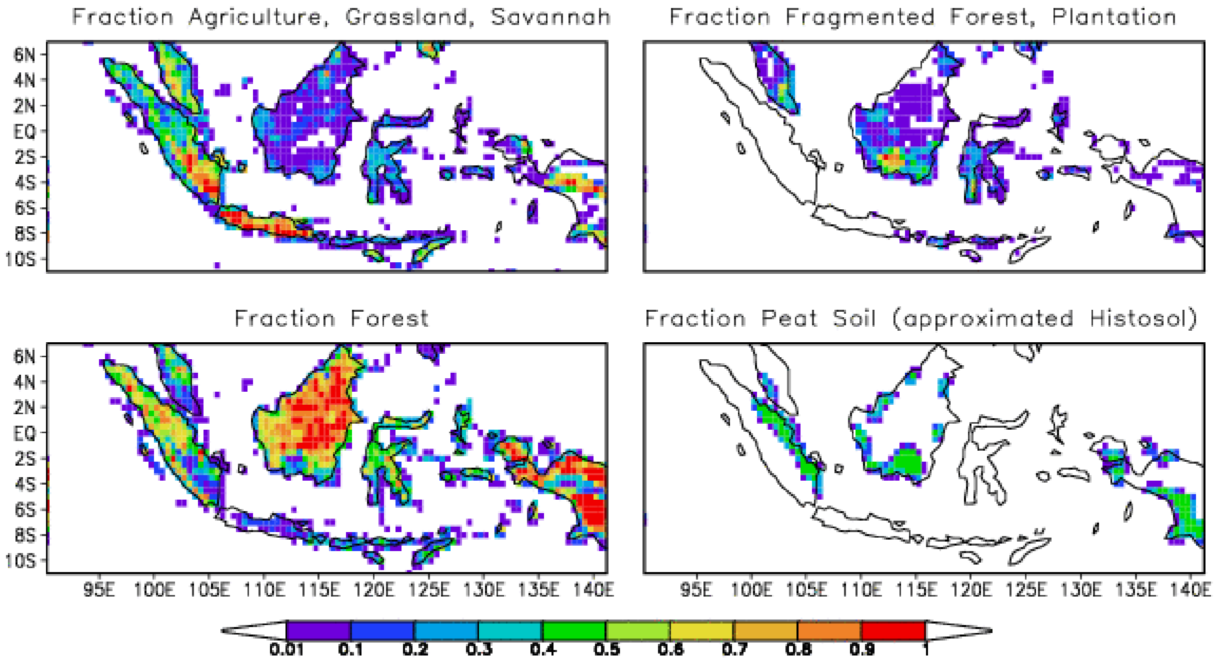


Figure 1. Some important surface libraries concerning on the vegetation type.

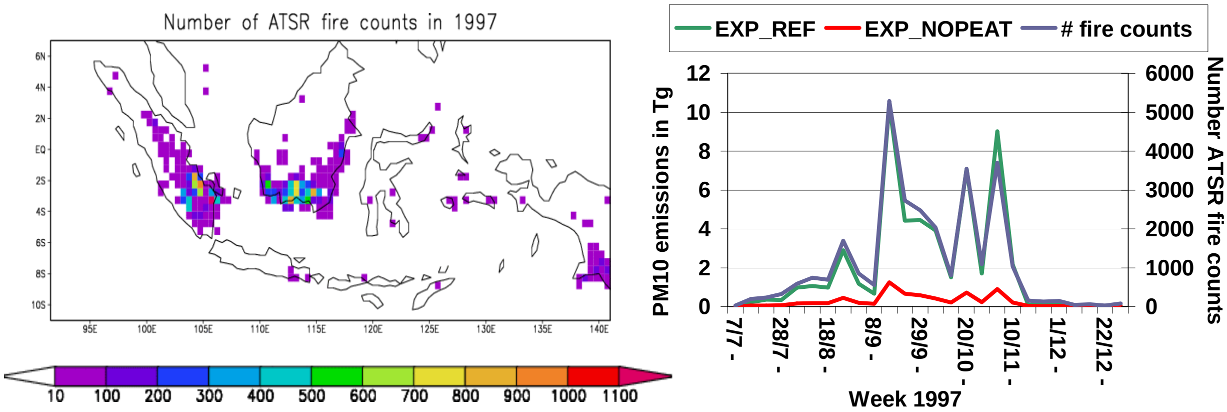


Figure 2. Total number of ATSR Algorithm 2 fire counts recorded in the second half of 1997 per 0.5*0.5° model grid (left), Weekly total PM10 emissions (right) in the second half of 1997 calculated for all fuel classes (EXP_REF) and for all fuel classes except peat (EXP_NOPEAT). On the secondary axis, the weekly number of ATSR Algorithm 2 fire counts is shown.

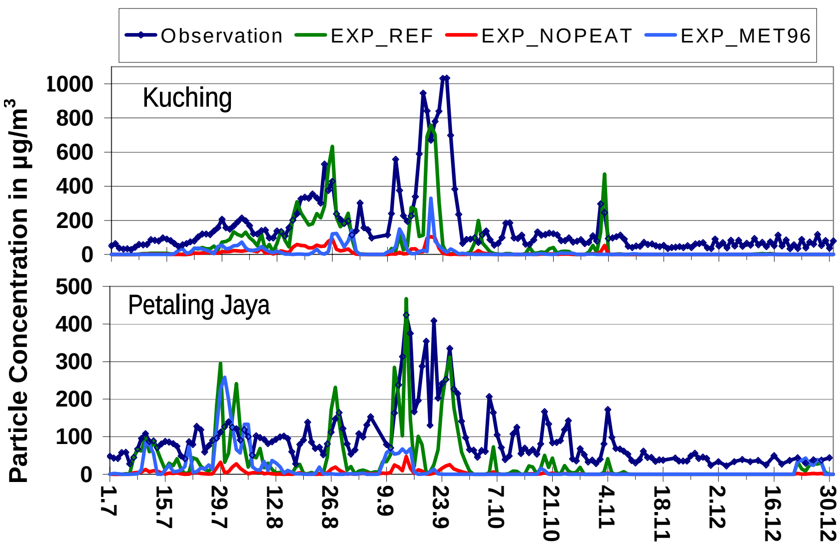


Figure 3. Comparison of daily mean PM10-concentration modelled for the lowest model layer and ambient particle measurements at Kuching and Petaling Jaya/Kuala Lumpur for the scenario runs (Data Source: Malaysian Meteorological Services).

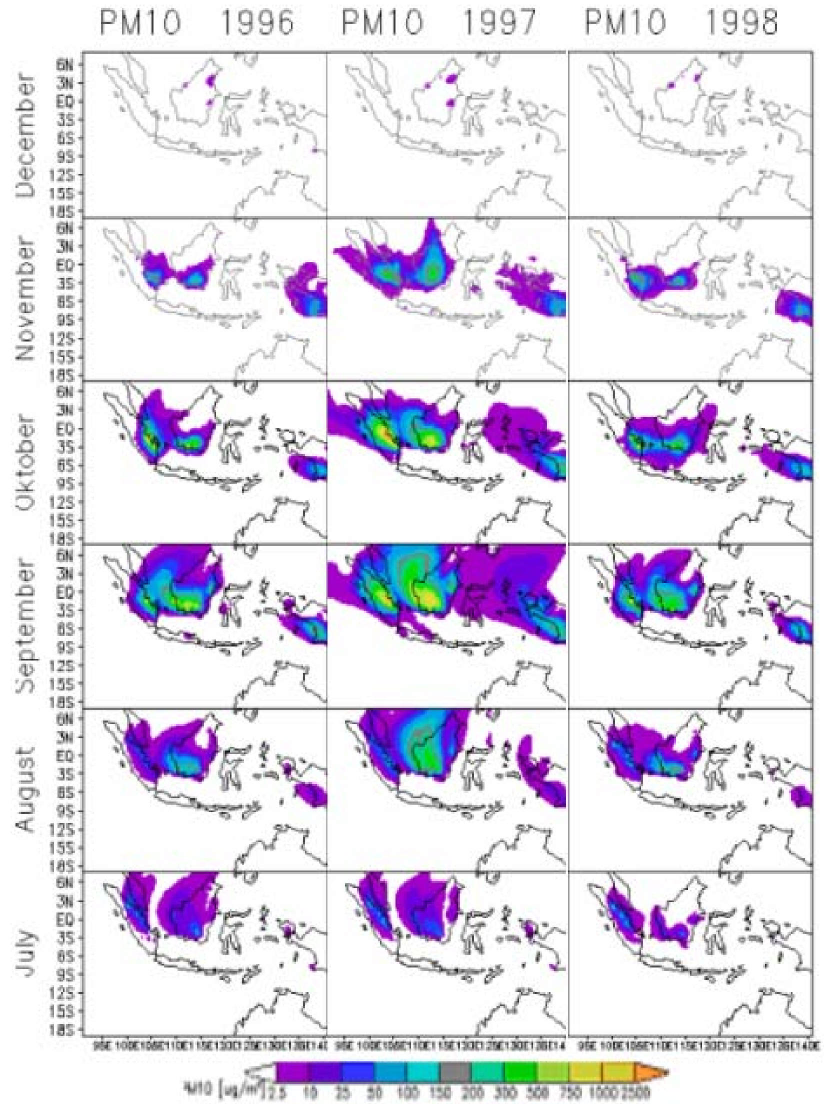


Figure 4. Simulated PM10 concentration with 1996, 1997 and 1998 meteorology, respectively, with a similar fire emission inventory data of July – December 1997.

FIRE USE STRATEGY IN PEATLAND AGRICULTURE: A SHOW CASE OF COMMUNITY CONTROLLED BURNING FROM WEST KALIMANTAN PROVINCE

Gusti Z Anshari
Faculty of Agriculture, Universitas Tanjungpura
Jl Ahmad Yani Pontianak 78124
Tel/Fax: (0561) 740191
Email: gzanshari@yahoo.com

ABSTRACT

Peat is known as marginal land for agriculture due to low acidity (pH), high Cation Exchange Capacity (CEC), low base saturation, low nutrients availability, and waterlogged environment that retard plant growths. A common recommendation is that only shallow peat (less than 1 meter) is considered suitable for agriculture. And the use of kinds of ameliorants such as ocean mud, charcoal, and volcanic ash, is also recommended. These scientific recommendations seem to be away from reality.

For peatland farmer community, there is no other alternative than fire use regardless peat depths. In West Kalimantan, small fire season would occur in February, and major fire usually takes place between June and August. Depending on the purpose of agriculture, open peatland would be wildly fired in order to fulfill subsistence needs. On the other hand, an important success factor of commercial peatland agriculture is controlled burning strategy. The use of ash from sawdust, temporary shelter, and compost is found to be a common practice, and proved to lead to good yields, and the maintenance of peat as a productive agriculture medium. In some cases, other farmers are tempted to use chemicals such as Nitrogen, Phosphorous, and Potassium in order to supply sufficient nutrients for crops. The scale of this peatland agriculture remains small because of market failure, poor technological innovation, and weak institution. These factors directly contribute to peat loss as it is shown by a symptom of haze associated with seasonal peat fire.

In order to maintain carbon storage in open peatland, it is essential to develop community based peatland agriculture development strategy. This includes the change from subsistence into market oriented farming, the development of community based agriculture business, and technological innovations that would reduce peatland oxidation and increase peatland productivity.

Keywords: community based peatland agriculture development strategy

TROPICAL FORESTS AND CLIMATE CHANGE ADAPTATION (TROFCCA): THE NEED TO DEVELOP METHODOLOGY FOR VULNERABILITY ASSESSMENT

Heru Santoso
Center for International Forestry Research
Jl. CIFOR, Situgede, Bogor 16680, Indonesia
h.santoso@cgiar.org

ABSTRACT

Tropical forest ecosystems, in particular those on which the livelihoods of people from several regions of the world depend, are among the most vulnerable ecosystems to changes in climate. Potential and observed impacts of climate change on forests added to other pressures like land conversion pose challenges to sustainably manage these systems.

Tropical Forests and Climate Change Adaptation (TroFCCA) is a project designed by CIFOR and CATIE that will contribute to the limited understanding of the adaptation of tropical forest ecosystem by developing robust methodologies to assess vulnerability of the ecosystems to climate change and to mainstreaming adaptation strategies into development agendas. The general framework of methodology will define a chain linkage between variables at various levels involving national development policy, society's interests, environmental goods and services provided by landscape heterogeneity (forests) and their ecosystem functions, and biophysical processes. Adaptation to the climate change and climate variability will be treated in parallel with the vulnerability assessments which will be addressed through policy dialogue that brings together various stakeholders. The policy oriented adaptation options will be defined after the vulnerability assessment with the involvement of forest management and those interested in the environmental goods and services provided by forest ecosystems. For its operation, TroFCCA considers following strategic approaches: (1) adaptation as part of the development policy, that is by including perspectives of the policy actors; (2) vulnerability assessments – not impacts, by understanding the system and its vulnerability in terms of climate, of which the assessments focus on the society and its dependence on forest ecosystems; and (3) landscape level focus, that is by recognizing and understanding the role of landscape heterogeneity (forests) in providing environmental goods and services as well as the role of many stakeholders in managing them.

General methodology allows the development of methods on the basis of national or regional needs and priorities that helps in mainstreaming the adaptation into development policy, and enhancing cooperation relating to work on adaptation. TroFCCA is also considering to explore the potential for innovative mechanisms to finance adaptation activities and compensate trade-offs as a mean for sustainable adaptation strategies.

Keywords: sustainable development policy, vulnerability assessments, various levels, mainstreaming adaptation.

WORKSHOP ON VULNERABILITY OF CARBON POOLS OF TROPICAL PEATLANDS IN ASIA

Jyrki Jauhiainen,
Department of Forest Ecology,
University of Helsinki, Finland.

SUMMARY

Introduction
Although tropical peat may comprise by area only 12% of the world's peatland resource, the carbon stored in it could represent nearly 30% of the total (Immirzi & Maltby, 1992; Lappalainen, 1996; Rieley & Page, 2005). Peatlands form important C-sink, but also own potential to release large quantities of greenhouse gases to the atmosphere, especially when the system functions are disturbed. Peat water table has crucial importance on the ecosystem's peat existence. If peat water table is permanently lowered, irreversible peat subsidence occurs, and the system transforms into a carbon source (Wösten & Ritzema, 2001; Jauhiainen *et al*., 2004; 2005). Carbon loss is repeatedly enforced by long lasting fires because each event is capable of degrading peat surfaces several decimeters (Siegert *et al.*, 2001).

Description of work
University of Helsinki has been part of two EU-funded research projects on tropical peat. It is currently involved in one EU-funded project (RESTORPEAT) as a partner and is running Academy of Finland funded project KEYTROP on the carbon related topic. We have been measuring carbon containing greenhouse gas fluxes at the upper Sungai Sebangau catchment, about 20 km southeast from the city of Palangka Raya in Central Kalimantan province of Indonesia since year 1999. Most of the sites are located inside the so-called Mega Rice Project (MRP) area that was target for intensive land development between the years 1995-1998. The area is in most parts clear felled and partially drained by inoperative canals dug for agricultural water management purposes. Carbon dioxide (CO_2) and methane (CH_4) fluxes have been measured from peat surfaces. Peat water table depth is appraised to be the primary factor controlling the C-fluxes in addition to the effects of vegetation. Possible differences in soil surface microtopography have been taken in account in the measurement facility setup. Soil temperatures at various depths and water table depth have been measured during gas flux measurements. The applied methods are described in the section *Type of data we have collected*.

Highlighted results
Results presented in this workshop are based on measurements in selectively logged forest, in clear felled repeatedly burned area, and in drained agricultural land. Soil surface gas flux rates were measured at various peat water table depths, and were then combined with an annual water table data in the study sites in order to produce estimate of cumulative gas fluxes for one year.

In terms of the greenhouse effect upholding gases, CO_2 seems to be clearly the more important gas in comparison to CH_4, both in the absolute quantity emitted and in terms of radiative forcing. Selectively logged forest floor CO_2 emission rates were highest among these three sites. Change of water table depth caused little effect on the CO_2 emission rates in forest floor except if the peat was water saturated. Root respiration and high fresh litter amount may likely explain the observed high CO_2 emission rates. In clear felled areas the emission rates were about ½-1/3 of the rates observed in the forest. CO_2 emission rates increased by increasing water table depth, but extreme dryness did not increase rates from vegetation free surfaces. Root respiration remains modest on cleared peat and the emissions were mainly from oxidizing peat. Detected CH_4 flux rates were in general low. Basically, CH_4 was emitted only in water saturated conditions. In sub surface water table conditions, peat CH_4 flux was near zero but peat could also show weak net CH_4 uptake.

The highest cumulative CO_2 emissions were formed in forest floor (see Table 1). On clear felled areas cumulative emissions were about 1/3 or less compared to the forest. Cumulative CH_4 emissions remained near zero. Peat on all three sites can be expected to function as a CH_4 source or sink depending on hydrological conditions during the year.

Table 1. Cumulative CO_2 and CH_4 fluxes in three sites differing by land use.

	Annual	
Site type	**CO_2 emission (g m^{-2} y^{-1})**	**CH_4 emission (g m^{-2} y^{-1})**
Selectively logged forest (near tree)	7598 ± 227	
Selectively logged forest (between trees)	7444 ± 399	-0.02 ± 0.15
Cleared burned area (high surface)	2255 ± 89	
Cleared burned area (depression)	2836 ± 361	0.08 ± 0.11
Farm field	1897 ± 124	0.04 ± 0.14

Type of data we have collected

Carbon dioxide and methane flux measurement sites have included two selectively logged forest sites (at hydrologically relatively intact area outside, and drainage affected area inside the ex-MRP area), reclaimed peat areas include clear felled recovering forest site, clear felled repeatedly burned site, and drained agricultural land. Currently we are studying the hydrological restoration effects on tropical peat carbon fluxes at the ex-MRP area.

Measurements have continued 1-3 years at each of the sites. The measurement occasions have been evenly distributed over year or have been made during 1-4 weeks lasting intensive study periods. As a background data, we have collected soil temperature and water table depth during the gas flux measurement. In data analysis, if continuous water table data is needed, we have relayed on our colleagues (Dr. H. Takahashi and Dr. T. Inoue) data. Starting from May 2004 KEYTROP project have had continuous water table measurements (Keller data logger) in 3 locations at the ex-MRP area.

Two methods have been applied for the gas flux measurements. Closed chamber technique has been applied for measuring CO_2 and CH_4 fluxes. In the method, gas samples collected from closed aluminium chambers are injected into 20 ml glass vials for analysis by gas chromatograph with a flame ionization detector (FID). Portable infrared gas analyzer (PP Systems, EGM-2 and EGM-4) connected to a small closed chamber has been used for measuring CO_2 emissions.

References

Immirzi CP. & Maltby E., 1992. The global status of peatlands and their role in the carbon cycle. Wetlands Ecosystem Research Group, Report 11, University of Exeter, UK.

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

Jauhiainen J., Takahashi H., Heikkinen JEP., Martikainen PJ. & Vasander H., 2005. Carbon fluxes from a tropical peat swamp forest floor. Global Change Biology 11: 1–10, doi: 10.1111/j.1365-2486.2005.01031.x

Lappalainen E. (ed.), 1996. Global Peat Resources. International Peat Society, Finland.

Rieley J. & Page S., 2005. Wise use of tropical peatlands, 2005. Rieley, J and Page, S. (Eds). ISBN: 90327 0347 1. Published by: ALTERRA - Wageningen University and Research Centre and the EU INCO - STRAPEAT and RESTORPEAT Partnerships. 237 p.

Wösten JHM. & Ritzema HP., 2001. Land and water management options for peatland development in Sarawak, Malaysia. International Peat Journal 11: 59–66.

GREENHOUSE GAS EXCHANGE IN RICE PADDIES ON TROPICAL PEATLANDS

Inubushi, K.1), Furukawa, Y.2), Itang, A.M.3), Tsuruta, J.4) and Yagi, K.5)

1) Chiba University, Matsudo, Japan (corresponding: inubushi@faculty.chiba-u.jp)
2) International Rice Research Institute, Laguna, Philippines
3) Jambi University, Jambi, Indonesia
4) The University of Tokyo, Kashiwa, Japan
5) National Institute for Agroenvironmental Sciences, Tsukuba, Japan

ABSTRACT

Peat soils contain 15~25% of terrestrial carbon and nitrogen, although they occupy only 3.3% of the land surface of the world (Batjes 1996). Approximately 29 million ha of peat lands (Histosols) are found in tropical regions, with more than half located in Indonesia (Driessen 1978; Takai 1997). Sumatra Island, Indonesia has 9.7 million ha of peat soils. Natural peat lands function as one of the important global carbon and nitrogen pools. Recently, large areas of native tropical peat lands have been converted to agricultural and aquacultural fields because of their location in flat lowland areas and an increase in population growth (Bouwman 1990; Sampson and Scholes 2000). If land reclamation is carried out, carbon and nitrogen cycling of the tropical peat soil could be altered. Because aerobic decomposition is suppressed by water saturated conditions, most native peat lands function as sinks of carbon and nitrogen (Sampson and Scholes 2000). When peat lands are reclaimed, drainage ditches are constructed to lower the groundwater level (Bouwmam 1990). It is considered that some part of the organic matter in tropical peat soil is decomposed to carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) due to land reclamation with drainage ditches. The loss of carbon and nitrogen does not only lead to global warming, but also to ground subsidence. Even though it is important to consider global warming and sustainable agriculture, there is little quantitative data on greenhouse gas emission from tropical peat lands (Bouwman 1990; Hadi et al. 2000, 2001). A carbon cycling model predicted that aerobic decomposition of the peat soil could be promoted to lower the groundwater level (Noordwijk et al. 1997). However, CO2, CH4 and N2O fluxes in peat soils and groundwater level did not show clear relationships in field investigations (Hadi et al. 2000, 2001). Unclear relationships might be due to the limited frequency of measurement and leaving seasonal changes out of consideration.

Monthly measurements of carbon dioxide CO2, methane CH4 and nitrous oxide N2O fluxes in peat soils were carried out and compared with groundwater level over a year at four sites; drained forest, upland cassava, upland and lowland paddy fields, located in Jambi province, Indonesia. Fluxes from swamp forest soils were also measured once per year as the native state of this investigated area. Land-use change from drained forest to lowland paddy field significantly decreased the CO2 from 266 to 30 mg C m–2 h–1 and N2O fluxes from 25.4 to 3.8 g N m–2 h–1, but increased the CH4 flux from 0.1 to 4.2 mg C m–2 h–1 in the soils. Change from drained forest to cassava field significantly increased N2O flux from 25.4 to 62.2 g N m–2 h–1, but had no significant influence on CO2 from 266 to 200 mg C m–2 h–1 and CH4 fluxes from 0.1 to 0.3 mg C m–2 h–1 in the soils. Averaged CO2 fluxes in the swamp forests 94 mg C m–2 h–1 were estimated to be one-third of that in the drained forest. Groundwater levels of drained forest and upland crop fields had been lowered by drainage ditches while swamp forest and lowland paddy field were flooded, although groundwater levels were also affected by precipitation. Groundwater levels were negatively related to CO2 flux but positively related to CH4 flux at all investigation sites. The peak of the N2O flux was observed at –20 cm of groundwater level. Lowering the groundwater level by 10 cm from the soil surface resulted in a 50% increase in CO2 emission from 109.1 to 162.4 mg C m–2 h–1 and a 25% decrease in CH4 emission from 0.440 to 0.325 mg C m–2 h–1 in this study. These results suggest that lowering of groundwater level by the drainage ditches in the peat lands contributes to global warming and devastation of fields. Swamp forest was probably the best land-use management in peat lands to suppress the carbon loss and greenhouse gas emission. Lowland paddy field was a better agricultural system in the peat lands in terms of C sequestration and greenhouse gas emission. Carbon loss from lowland paddy field was one-eighth of that of the other upland crop systems, although the Global Warming Potential was almost the same level as that of the other upland crop systems because of CH4 emission through rice plants.

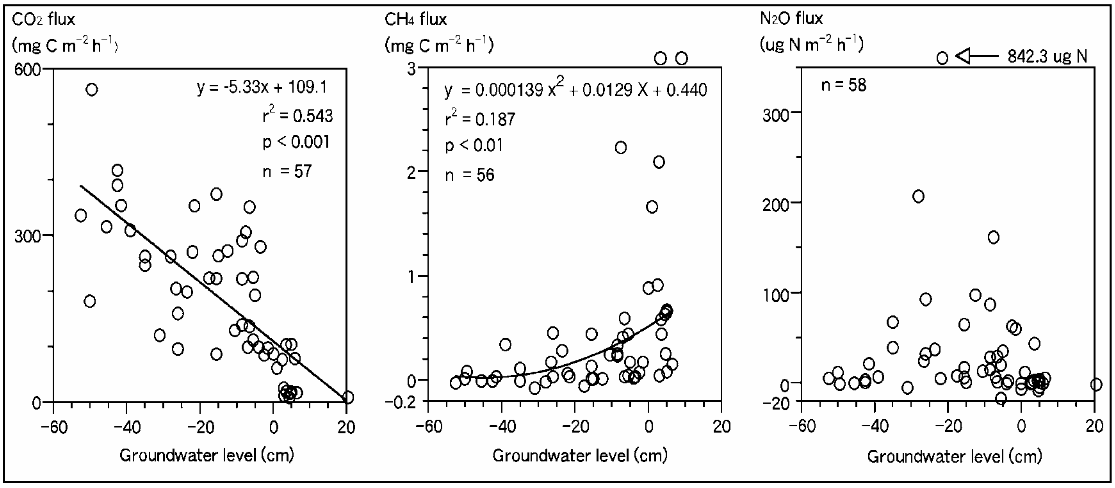


Fig. Relationship between groundwater level and greenhouse gas flux in tropical peatlands, Jambi, Indonesia (Furukawa et al., 2005)

Furukawa, et al. Nutrient Cycling in Agroecosystems 71: 81–91, 2005.

LOAGAN BUNUT PEAT STUDY – A PRELIMINARY REPORT

Lulie Melling[1], Alex Sayok[2], Lah Jau Uyo[1], Hatano Ryusuke[3], Mitsuru Osaki [3] and Jack Liam[4]

[1]*Department of Agriculture, Jalan Badruddin, 93400, Kuching, Sarawak, Malaysia*
[2]*Peat Swamp Forest Project UNDP/GEF Funded, FRIM, 52109 Selangor, Malaysia*
[3]*Graduate School of Agriculture, Hokkaido University, Sapporo, 060-8589, Japan*
[4]*Forest Department Sarawak, 93660 Kuching, Sarawak, Malaysia*

ABSTRACT

Tropical peatlands contribute significantly to terrestrial carbon (C) storage because of their considerable thickness and high C content. Presently, a large proportion (between one fifth and one third) of global soil C is located in tropical peatland. The tropical peat carbon store is estimated at more than 70 Gt or up to 20% of global peatland carbon.

The Loagan Bunut National Park (LBNP), gazetted in 1990 was primarily to protect the huge inland lake, the peat swamp forest, and the associated flora and fauna-covers an area of 10, 736 ha. It is located between the Tinjar and the Teru Rivers in the upper reaches of the Baram River Basin in northern Sarawak, Malaysia. The tropical peatland of LBNP is a unique ecosystem. The park composed of more than 70 % peat swamp forest with a mosaic of wetland habitats and a tropical rainforest on the hilly sites. The 650-hectare lake, Loagan Bunut, located in the center forms the main attraction as it teems with wildlife during both high and low water level conditions. The current land development surrounding the National Park, now threatens its ecological balance, which makes it one of the most fragile wetland systems in the world. A peat soil study is currently being carried out to evaluate the characteristics of the peat swamp at the National Park, which is in conjunction with the UNDP/GEF funded project on the Conservation and Sustainable Use of Tropical Peat Swamp Forests and Associated Wetland Ecosystems. Specifically, we would then be able to assess the peat depth, topography of the peat basin, peat profile morphology, and physical and chemical properties of the peat in relation to the forest type on the peat basin. Information gathered would be a very valuable assets for formulating an effective approach of managing the peat resource for the management, protection and conservation of the LBNP.

Six traverse lines across the peat swamp: from Loagan Bunut lake to Batang Tinjar and traverse lines from Sg.Teru to Batang Tinjar were undertaken. Initial results showed that the peat surface at LBNP was like an inverted saucer creating a dome shape cross-section. The peat depth generally increased quite rapidly towards the center of the peat swamp with a slope up to about 4 %. The base of the peat depth was irregular giving a wide range in peat depths with probably the deepest peat ever recorded in the world at 20.7m at Rentis 6. Generally, even though the peat in LBNP was among the deepest tropical peat in the world, it was generally quite humified in nature. This maybe due to the high and large fluctuation in the water table, which was closely related to the water status of the bordering lake. The peat characteristics in relation to its topography had also influence the structures and floristic composition of the LBNP.

SUSTAINABLE FIBER PLANTATION OPERATIONS ON PEATLANDS IN THE KAMPAR PENINSULA

Mark Werren [1]
Riau Andalan Pulp and Paper
Asia Pacific Resources International Holdings Limited

ABSTRACT

The peatland ecosystem is unique. From the carbon balance point of view, a peatland area is a large carbon stock reservoir. Any disturbance to the natural state of the peatland ecosystem will likely upset this carbon balance either by increasing the inflow or, of greater concern, the outflow. Since the early 1990s, recognition of the role of accumulation of carbon and other greenhouse gases in the atmosphere in enhancing global warming has been consistently stronger. Interests in the study of carbon cycles contributes significantly to the global efforts to reduce and reverse the accumulation of carbon and other greenhouse gas emissions in order to mitigate global warming.

The carbon cycle in a peatland ecosystem depends on a number factors, namely the stock of carbon in peat domes below-ground and secondarily in the above-ground forest biomass; the relatively insignificant (compared to the amount of carbon stock in the peat dome) inflow largely in the form of vegetation uptake (sequestration); and potentially significant outflow in the form of subsidence, forest and peat fires; and degradation of forests and other vegetative covers. The main drivers of the changes of the carbon balance are influenced by a number of secondary causes. For example, degradation of forest cover will be enhanced by land-clearing and illegal logging, or halted by conservation and reforestation.

Subsidence of peat surfaces can be mitigated by maintaining good humidity of the peat dome that is also influenced by the extent of the coverage of forest canopy and by good hydrological management. Subsidence of peat is a natural effect of drainage — reduction of the water table underneath the peatland. Natural or (direct and indirect) anthropogenic changes of the hydrological system or indirectly by direct exposure of the peatland to sunlight due to reduced forest and vegetative cover will change the hydrological system. Changes in forest cover may also be influenced by development activities in the region that, in turn, are influenced by socio-economic and institutional (laws, regulations, shifts in community traditions, etc.) drivers. For example, rampant illegal logging and land-use change may be caused by socio-economic pressures in the surrounding community. Land cover change can also be caused by regulatory drivers that pay little attention to ecological impacts of such regulations.

Riau Andalan Pulp and Paper (RIAUPULP) is an Indonesian subsidiary of the Singapore-based Asia Pacific Resources International Holdings Limited (APRIL), and is a leading producer of fiber, pulp and paper. It has an existing capacity to produce 2 million tons of pulp per year and is developing Acacia plantations as sustainable sources of raw material. As of December 2005, the company had established an aggregate plantation estate of 260,000 hectares within its own concession area, joint ventures with other plantation companies and community fiber farms. With the continued threat of forest destruction caused by illegal logging and other unsustainable land management practices in the Kampar Peninsula, RIAUPULP offers the sustainable alternative for the development of these resources through active management intervention to develop a 100,000 ha “ring” in the outer boundary of the Kampar Peninsula, using only about 70,000 hectares mainly for Acacia plantations and conserving the remaining 30,000 ha within the concession areas, including HCVF (High Conservation Value Forest) areas. The remaining 300,000 ha of the peatland, i.e. the inland “core” — or 75 percent of the peninsula — is proposed to become a protected conservation area. The question is as follows: in which direction and to what extent this Kampar Peninsula development plan will change the carbon balance?
But even without the presence of the “ring” development, if current activities in the peninsula are left unmitigated, (formal and informal, legal and illegal) clearance activities will continue to deteriorate and, without proper hydrological management, cause massive subsidence in the peninsula which will result in carbon losses.

Indeed, the planned intervention by RIAUPULP will change the carbon balance of the peatland in the Kampar Peninsula. With the assumption of about 4,800 tons of carbon per hectare, the Kampar

[1] With contributions from Dr Agus Sari, PT Pelangi Energi Abadi Citra Indonesia

Peninsula is a reservoir of an estimated 2 billion tons of carbon. RIAUPULP's proposed intervention includes commencing a moratorium of current development practices in the 300,000 ha inland "core" of the peninsula. This proposal alone will reduce subsidence considerably, the extent to which remains to be assessed. The development of the "ring" with tree plantations and an adequate buffer zone will add to the controlled subsidence, at about 1 meter in the first year and about 0.1 meters in subsequent years. This means that with up to 5 meters total subsidence in the 70,000 ha plantation area in 50 years, an equivalent of about 200 million tons of carbon may be released due to oxidation. In order for the ring to be productive and the water table to be maintained at a sustainable level, however, hydrological and forest cover conservation in the inland "core" is imperative.

In the first years of operation, the remaining secondary forest in the "ring" area will have to be cleared. Clearing 70,000 ha of degraded residual forest cover for plantation will remove a significant amount of carbon. However, in the future, carbon uptake by Acacia plantations may offset the loss of carbon due to the land-clearing. The carbon losses in the plantation, therefore, are only due to the subsidence. This needs to be measured and monitored in the long-term. Fire adds additional risks to carbon release. Both above- and below-ground carbon will be released by uncontrolled fires. RIAUPULP works to minimize the risk of fires and to contain any outbreaks to less than 10 hectares in extent.

RIAUPULP has been involved in developing the surrounding communities, not only to educate them on the risk of fires and measures to mitigate them, but also to provide better knowledge on agricultural practices in the area. The extent to which the community development activities result in alternative livelihoods for illegal loggers remains inconclusive, but a deliberate link between sustainable livelihood programs in the community development activities is beginning to reduce the pressure to carry out illegal logging and other unsustainable forest practices.

It is preliminarily concluded that subsidence constitutes the single largest source of carbon outflow from the Kampar Peninsula. Within RIAUPULP's concession inside the "ring" and due to the first-year land clearing and subsequent planting and harvesting cycles, there will be significant amounts of carbon released in the course of 50 years. Additional subsidence may occur outside of RIAUPULP's concession areas, especially in the inland "core" that is supposed to be protected, adding some more carbon to be released in the same period.

The alternatives to the plantation development proposed by RIAUPULP, however, are likely substantially more detrimental. Subsidence occurring through piecemeal unprofessional drainage during conversion of existing forests for agriculture and other purposes and uncontrolled (and largely illegal) logging will cause significant losses in the amount of carbon per year from peat oxidation. If no mitigation measures are in place, in the course of 50 years, it is apparent that the whole area will have been completely clear-cut and the entire peat area lost.

It is generally understood that the ideal option to reduce the release of carbon from the Kampar Peninsula is by keeping the entire 400,000 ha area intact and protected. By now, however, this option is already infeasible. Therefore among the remaining feasible options, the most sustainable is the "ring" tree plantation development master plan. This includes tightly controlled hydrological management and complete multi-stakeholder protection of the inland "core" as a conservation area. We believe that on the "ring" ex-forest sites and in comparison to other forms of land-use including agriculture, perennial tree plantation crops with low nutrient requirements, fast canopy closure and harvesting only once in 5-years, are the most sustainable land-use to minimize subsidence and conserve carbon in the ecosystem.

CARBON FLUX FROM PEAT SWAMP FOREST: PRELIMINARY OBSERVATION

Philip,E, L.K. Kho and Abdul Rahim Nik
Forest Research Institute Malaysia (FRIM)
52 109 Kepong, Selangor, Malaysia

ABSTRACT

Current evidence suggests that a large release of carbon from tropical deforestation, and partially offset by large sink in undisturbed forest or smaller release of C from deforestation and little sink in undisturbed forest. However, these differences in carbon flux in tropics could be due to lack of data and methodological limitations.

This paper provides a summary of carbon flux from peat swamp forest in comparison with other types of forest, mainly inland and mangrove forest of Malaysia. It provides a preliminary synthesis on available forest areas, biomass and harvest index against land-use change. The study was carried out following the IPCC 1996 guidelines. Carbon biomass and flux were estimated for the different forest types and a comparison is made between these forest types. Estimations derived from biomass and carbon expansion factors. Soil efflux was measured with LICOR 6400.

Preliminary findings showed that the forest in Malaysia is a cradle for carbon stocks (Table 1). Inland forest had the highest above ground carbon stocks by virtue of largest type of forest. Both peat swamp and mangrove forest had been lost to other land use.

Table 1 : Distribution and Extent of Major Forest Types

Forest Type	Area (ha)	Total Carbon stocks (kt C)
Inland forest	18.5	203500
Peat Swamp	1.31	14554.1
Mangrove	0.57	5392.2

Peat swamp forest forms about 6.5% of the total forest in Malaysia. The annual carbon uptake for above ground is estimated at 3415.08 kt C while the annual carbon release is 1427.51 kt C for peat swamp forest (Table 2). A comparison between the different forest type for carbon uptake and release is shown in Table 2.

Table 2: Carbon uptake and release by different forest type.

Forest Type	Total Carbon Uptake (kt C)	Annual Carbon Release (kt C)
Inland forest	25510	7946.9
Peat swamp	3415.08	1427.51
Mangrove	676	-

Preliminary soil carbon efflux and soil organic carbon is reported in Table 3. Both SOC and soil CO_2 efflux were higher in the peat soils and were in line with observation elsewhere. The higher values were indicative of peat characteristic, containing higher decomposed plant materials, thus higher soil CO_2 efflux.

Table 3: Table 5: Comparison between soil organic carbon (SOC) and soil CO_2 efflux Between inland forest and peat swamp.

Forest Type	SOC (t ha^{-1})	Soil CO_2Efflux (t ha^{-1} yr^{-1})
Inland forest*	120	31
Peat swamp#	200	42

* Pasoh FR # Oil palm

CLIMATE AND HUMAN DRIVERS OF FIRE ACTIVITY AND EMISSIONS FROM PEAT FIRES IN BORNEO, 1997 TO 2003

Allan Spessa[1,2,3], Angelika Heil[4], Florian Siegart[5], Uli Weber[1,6]

1. Max Plank Institute for Biogeochemistry, Jena, Germany.
2. Associate Scientist of QUEST (Quantifying & Understanding the Earth System), Bristol, UK.
3. Hadley Centre for Climate Predictions and Impacts, Met Office, Exeter, UK (from mid-2006).
4. Max Plank Institute for Meteorology, Hamburg, Germany
5. Remote Sensing Solutions GmbH, Munich, Germany.
6. Friedrich Schiller University, Jena, Germany.

Fire is a significant determinant of vegetation dynamics, biogeochemical cycling and atmospheric chemistry at global, regional and landscape scales (Pyne *et al.* 1986; Crutzen & Andreae 1990; Bradstock *et al.* 2002). It is evidently increasing in frequency across the Tropics with often negative impacts on biodiversity conservation, carbon stocks, and emissions of greenhouse gases and other pollutants to the atmosphere (Lagenfelds *et al.* 2002; Cochrane 2003; van der Werf *et al.* 2004). Page *et al.* (2002) estimate that the widespread fires associated with the exceptionally strong drought during the 1997 El Nino Southern Oscillation (ENSO) event in Indonesian forests and peat swamps released the equivalent of about 13-40% of global fossil fuel emissions of CO2 released that year. Further work indicates the total amount of emissions from Indonesia's 1997 fires was 3.04 Gt C or 1.52 ppm of CO2, which effectively doubled the (previously accounted) global annual CO2 growth rate for 1997 (Murdiyarso 2003). While the El Nino drought of 1997 provided extremely dry conditions suitable for extensive burning across much of Borneo, hotspots of fire activity were concentrated in southern Kalimantan around areas subject to large-scale land clearing and peat drainage connected with the Mega Rice project (Page *et al.* 2002). The 1997 ENSO event extended well into 1998 (creating the so-called 'drought of the century' across SE Asia), and Siegart *et al.* (2001) demonstated a marked spike in burning activity during this period linked to deforestation. Although 2002 was also an EL Nino year, albeit weaker in magnitude than 1997-98, we are aware of no long-term assessments of fire activity and emissions from peat fires in relation to the ENSO cycle and land cover change in SE Asia. Such assessments can help inform us about how future changes in rainfall and land cover may determine the incidence of peat fires, as well as the severity of associated emissions.

Focusing on the island of Borneo (comprising Kalimantan (Indonesia), Sarawak and Sabah (Malaysia), and Brunei) during the period 1997-2003, and using rainfall and soil data in combination with state-of-the art satellite sensor data (LANDSAT, MODIS, ATSR and AVHRR) to determine burnt area and deforestation patterns, we asked:

1. How does ENSO affect precipitation and fire frequency?
2. What are the relative effects of ENSO and deforestation on spatio-temporal patterns in fire activity?
3. What are the carbon and trace greenhouse gas emissions from fires in peat, forests and in non-forested areas?

Results and Discussion

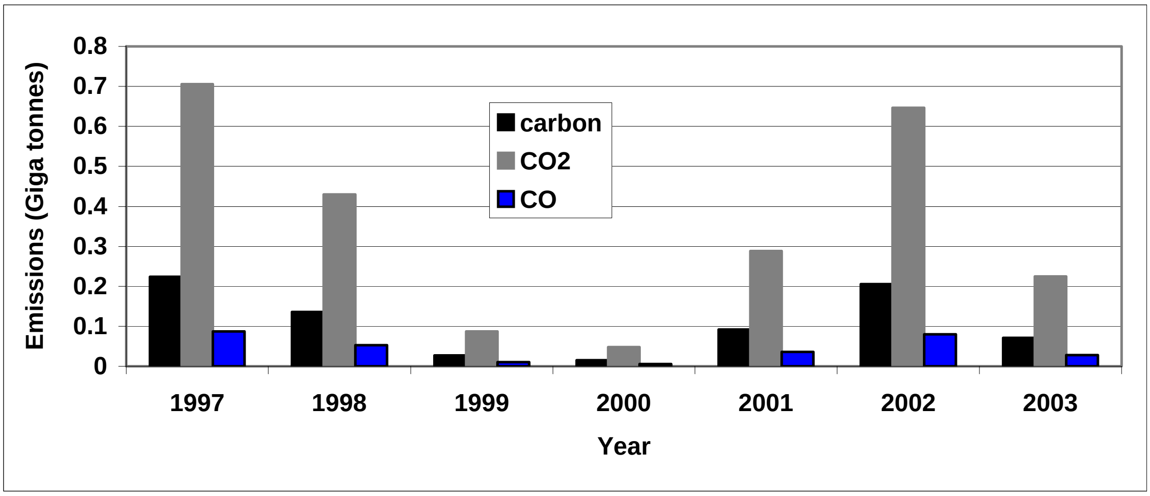
Fire activity across Borneo during 1997-2003 was correlated with ENSO-driven rainfall variability, however, this relationship was spatially highly variable and reflected deforestation and differential land use patterns. The correlations between area burnt and prior rainfall were strongly negative in areas of southern and eastern Kalimantan that had undergone extensive net losses in land cover between 1997 and 2003. They were generally weak or almost non-existent in other parts of the island that had exhibited either a net gain in land cover or no net change in land cover during this period (even though most of these areas were also affected by ENSO rainfall variability).

Emissions of trace greenhouse gases from peat fires in Borneo were, on the average, an order of magnitude greater in El Nino years compared with non-El Nino years (Fig. 1). These estimates include several assumptions: i) peat comprises dystric histosols and humic gleysols; ii) the maximum depth of each peat type is 250 cm and 40 cm, respectively, and iii) if a fire hotspot coincides with a peat pixel (1-1.2 sqkm) in a particular month, then it always combusts to a depth of 25 cm and 20 cm, respectively, in that month, and then it extinguishes. Around 90% of the calculated emissions arose from peat fires in southern and eastern Kalimantan. While the area of Kalimantan peat is 2.5 times greater than non-Kalimantan peat (63474 versus 24527 sq kms), we note that the proportion of peat burnt in

Kalimantan between 1997 and 2003 (40%) was 3.5 times higher than non-Kalimantan peats (11%). Furthermore, there was a close link between deforestation, land management and elevated peat burning. In peatland areas of Kalimantan that had a net loss in land cover between 1997 and 2003, we found a strong positive correlation between area burnt and land cover change (R^2 close to 1). By contrast, there was no correlation between area burnt and land cover change either in Kalimantan peatlands that had a net gain in land cover during this period, or in non-Kalimantan peatlands.

We recalculated peat emissions across Borneo, 1997-2003, by modifying the third assumption and using instead: i) a simple model of water table depth as a function of prior rainfall based on empirical data recorded at a forested site in central Kalimantan (Takahashi *unpubl.*); and ii) a determination of depth combusted as a linear function of water table depth. These changes produced a marked reduction in emissions across time and space reflecting differential peat moisture patterns with respect to changing water table depth. In 1998, however, the reductions are unusually large resulting in comparatively few emissions that year. The second method has several potential sources of error. Notably, the CRU rainfall surfaces we used (available at 0.5 deg resolution from the Climate Research Unit, University of East Anglia: http://www.cru.uea.ac.uk/cru/data/), in particular, those for March and April 1998, indicate rather high rainfall for eastern Kalimantan, although this region was practically obliterated by fire then. Rainfall data from the GPCC (Global Precipitation Climatology Centre, German Weather Service) (http://www.dwd.de/de/FundE/Klima/KLIS/int/GPCC/GPCC.htm) appear better matched to the fire patterns than CRU rainfall, but GPCC data are only available at one degree resolution. Another source of error, applicable to both the first and second methods, is that we have not accounted for the effect of peat drainage on peat moisture. However, data on the extent and impact of peat drainage are, to the best of our knowledge, limited to only a few locations; and are therefore difficult to extrapolate.

Given that an El Nino event will return to Borneo, probably in the near future, we highlight the need for urgent policy attention to address the associated challenges of ongoing deforestation, land mismanagement, high fire frequency and large-scale emissions from biomass burning there.



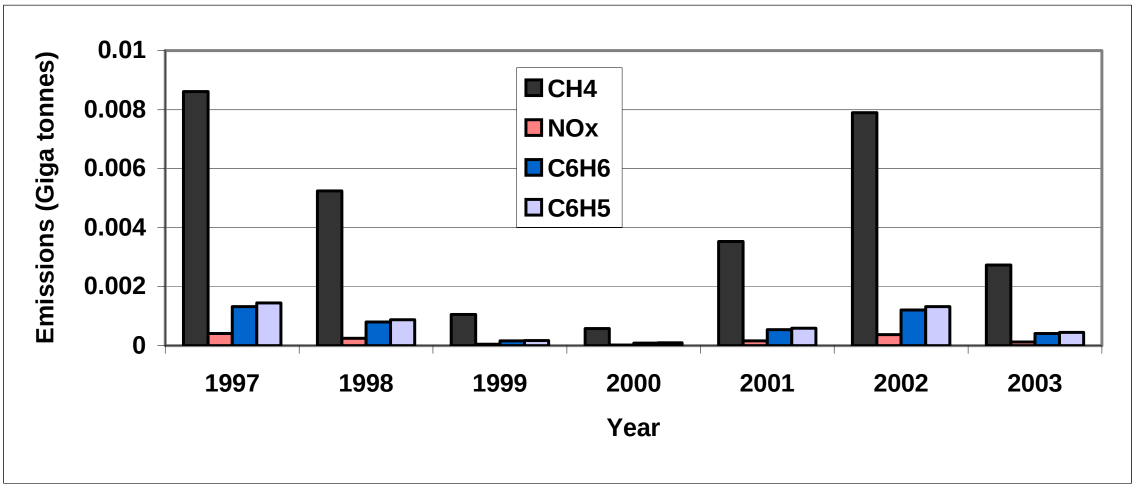


Figure 1 Annual total emissions of carbon and trace greenhouse gases from peat fires in Borneo, 1997-2003.

Potential data contribution towards further collaborative work

1. Georeferenced monthly fire hotspots across Borneo, 1997-2003.
2. Georeferenced monthly emissions of carbon, CO2, CO, CH4, NOx, C6H6 and C6H5 from peat fires, forest fires and non-forest fires across Borneo 1997-2003.
3. Digital peat map of Borneo (FAO).
4. Digital 1994/95 AVHRR ConTree and MODIS 2001 ConTree maps for Borneo.
5. Monthly CRU rainfall and other climate fields @ 0.5 deg for Borneo, 1997-2003.
6. Monthly GPCC rainfall surfaces @ 1 degree for Borneo, 1997-2003.
7. Population density @ 0.5 deg for Borneo, 1997-2003.

SUMMARY OF RELEVANT TROPICAL CARBON RESEARCH INTERESTS

Susan Page
Dept. Geography, Univ. Leicester, UK
sep5@le.ac.uk

ABSTRACT

The Late Quaternary peatland archive

- Our research has established that the formation of contemporary peatlands in SE Asia has occurred over a much longer time scale than was previously acknowledged. Peat genesis in coastal areas began around 4000-5,500 y BP. Sub-coastal and inland peatlands had much earlier initiation dates, ranging from Late Pleistocene (~29,000 y BP) in W. Kalimantan (Anshari et al., 2001, 2004) to ~26,000 y BP in C. Kalimantan (Page et al. 2004) through to early Holocene (8,000-9,000 y BP) for other high and basin/valley peatlands within Borneo (Sieffermann et al. 1988; Staub & Esterle 1994; Neuzil 1997). This has implications for global carbon modeling. It had been assumed previously that tropical peat accumulation was primarily a feature of the Holocene; it is now clear that it was also an important element of the last glacial period. The discovery of an extended palaeo-record will make an important contribution to knowledge of the longer-term behaviour of the peatland carbon reservoir.
- Carbon allocation rates in tropical peatlands in the past have been very high. During the Late Pleistocene/early Holocene (8540-7820 y BP), inland peatlands in C. Kalimantan had peat and carbon accumulation rates of 2.55 mm yr^{-1} and 92 g C m^{-2} yr^{-1}, respectively. These values are three to four times greater than accumulation rates reported for the same period in temperate and boreal bogs, which are about 20 to 25 g C m^{-2} yr^{-1} (Turunen & Turunen 2003).
- Using sequences of peat dates it has been possible to hypothesise that some tropical peatlands have undergone significant oxidation and peat loss at periods in the past.
- In the absence of human intervention, many tropical deposits are currently either accumulating peat, in a steady state, or undergoing natural degradation (Sieffermann et al. 1988; Page et al. 1999). The current average accumulation rate for Indonesian peatlands has been estimated to be 1-2 mm yr^{-1} (Sorensen 1993; Page et al. 2004).
- The average long-term (apparent) rate of carbon accumulation (LORCA) value for an inland peat deposit in C. Kalimantan is 56 g C m^{-2} yr^{-1} (Page et al. 2004).

Impacts of land-use change and fire on tropical peatland carbon dynamics

- During 97/98 fires affected large areas of Indonesia's peatlands. We estimated the amount of carbon released from combustion of vegetation and peat (0.81- 2.57 Pg) corresponded to 13-40% of the annual global carbon production from fossil fuels. Up to 8% of the total peat carbon store was released in a few months, equivalent to 1000-2000 years of carbon accumulation (Page et al. 2002). The transfer of large amounts of carbon to the atmosphere has major implications for climate change processes.
- Current and future research focuses on producing new estimates of carbon losses arising from land use change and fires since 1997; measurements of biomass/fuel loadings; and experimental work on gaseous emissions (GHGs) from fires (using a combination of ground and earth observation data).

Role of fire in the vegetation dynamics & restoration of tropical peatlands

- A database of archive satellite data has been collated for a study area in C. Kalimantan. Appropriate techniques are being developed to map extent, location and quality of forest fragments over the past 25 years and provide a burn history for fire-affected areas. These data will be used to monitor vegetation regeneration on former burn scars and investigate the role of remnant forest fragments in the recovery process. This will be done both remotely (using satellite data) and in the field.
- Further research is using data supplied by the Disaster Monitoring Constellation satellite and other current satellite data sets to establish the spatial extent, timing, quantity and intensity of future fire events (2005-2007) and the impact of water table manipulation on peatland hydrological and ecological conditions.

Studies of forest biodiversity, biomass and forest restoration

- Studies of above and below ground biomass have demonstrated differences between peat swamp forest sub-types. Total above-ground forest biomass in C. Kalimantan varies from 314

t ha^{-1} (marginal mixed swamp forest, peat 2-3 m thick) to 252 t ha^{-1} (low canopy pole forest, peat >7 m thick) (Sulistyanto, 2004; Page & Waldes, 2002).

- Work commencing summer 2006 will involve studies of forest regeneration and restoration, focusing on seed dispersal, seed bank status and seedling recruitment.

Type of data available for synthesis papers/integrative studies

- Data on peat depth/volume and peat carbon store for parts of C. Kalimantan.
- Data on peat accumulation/carbon storage rates
- Data on role of fires & land use change in atmospheric carbon emissions
- Data on role of fires & land use change in vegetation dynamics
- Forest biodiversity, biomass, regeneration

COMPARISON OF CO_2 EMISSION AND SEQUESTRATION USING NETPRO V.1.1: STUDY CASE OF FOREST FIRE IN CENTRAL KALIMANTAN

Tania June[1,2], Hendrik Segah[3], T.Hirano[5], Lilik Slamet[4],
Takashi Kohyama[5] and Mitsuru Osaki[5]

[1]Seameo Biotrop, [2]Bogor Agricultural University-Indonesia, [3]University of Palangkaraya-Indonesia, [4]LAPAN-Indonesia and [5]Hokkaido University-Japan

ABSTRACT

Central Kalimantan peatland forest had been destructed rapidly due to human activities. In 1995-1997, the Indonesian government opened the forest intended for agriculture project. During that period about 4,600 kilometers of canals were open, some as wide as 30 meters. The canals resulted in making the peatland forest dry, increasing CO_2 emission and very vulnerable to fire.

This paper intended to estimate CO_2 emission from forest fire and absorption of forest growth using Remote Sensing and GIS combined with modeling. The study area is chosen in Kalampangan Peatlans Forest, Central Kalimantan, Indonesia. Forest fire data was taken from fire occurrence in year 2002. Absorption of CO_2 by vegetation growth was estimated using data derived from remote sensing images year 2003 and 2004.

Emission is estimated using software application NetPro v.1.1, where emission is estimated from amount of burnt biomass derived from remote sensing data. Absorption is estimated using Net Primary Production approach, as followed:

$$NPP = e \cdot f_{APAR} \cdot PAR \cdot \tau \cdot \omega$$

where e is radiation use effiency (gC MJ^{-1}); f_{APAR} is fraction of PAR absorbed by canopy; PAR is photosynthetically active radiation (MJ); τ is temperature reducing factor and ω is water limitation reducing factor.

NetPro v. 1.1 is written in Visual Basic 6.0, equipped with MapObjects 2.1 as middle ware. Input data, shapefiles of burnt areas and climate characteristic are prepared using ERMapper 6.4 and ArcGIS 9.0. Output of model is estimated total emission and estimated absorption of CO_2.

HOW TO ESTABLISH NEW INTEGRATED SCIENTIFIC FIELD FOR CARBON CONTROL IN ECOSYSTEM

Mitsuru OSAKI
Graduate School of Agriculture, Hokkaido University
Kita-9, Shishi-9, Kitaku, Sapporo 060-8589, JAPAN
E-mail: mosaki@chem.agr.hokudai.ac.jp

Takashi KOHYAMA
Graduate School of Environmental Earth Science, Hokkaido University
E-mail: kohyama@ees.hokudai.ac.jp

ABSTRACT

Carbon storage (Gt C) is estimated as 4,130 in fossil fuel, 1,800-2,200 in terrestrial biosphere, 38,400 in ocean, and 720 in atmosphere (Environmental Science by R.T. Wright & B. J. Nebel, Pearson Education, 2002). Terrestrial biosphere and ocean are carbon sink by 0.6-2.2 and 1.4-2.6 (Gt C/year), and fossil fuel conversion is carbon source by 6.5 (Gt C/year). By IPCC report, carbon storage (Gt C) in soil and vegitation is estimated as 951-1,555 and 262-880. Thus, as carbon pool is extremely large in terrestrial biosphere and ocean, global carbon cycle have catastrophically damage by destruction or disturbance of two ecosystems. Terrestrial ecosystem is extremely fragile, and carbon storage is more in soil than vegetation, indicating that soil carbon management is first priority to study. Vegetation disturbance, soil management, cultivation system, and climate changing affect soil carbon. Soil carbon-rich ecosystems locate in boreal peat, black soil, and tropical peat, but now a day unfortunatelly these ecosystems have been seriously destroyed by climate changing and human activity.

Still we need more detail carbon observation in three ecosystems, and at a same time we must develop technology for more carbon storage in soil sphere. It is assumed that soil carbon accumulate extremely in wet and poor/adverse nutrient, or wet and cold. Wet condition is disturbing by land development or drought by climate change, which cause wild fire and cold fire (organic matter decomposition) by microorganisms. Poor/adverse nutrient condition is also important for carbon storage in soil, especially in tropical rigion, which is destroyed by fertilizer application or chemical deposit. Cold condition is changing by global worming, by which permafrost in boreal peat have been melting. As before 20 Century, these fragile ecosystems were not disturbed much, very few studies on conservation and rehabilitation of these ecosystems have been done until now. Pioneer study on these ecosystems revealed very difficulty of rehabilitation. Modern cultivation technology has been developed by using chemical fertilizer, however in this fragile ecosystem, chemical fertilizer accelerates more decomposition of soil organic matter. Therefore we must develop alternative technology, which must be minimum impute chemicals technology. New alternative technology for both vegetation rehabilitation and soil carbon storage must be based on symbiotic system with microorganisms, for which we concentrate on study of rhizoshere and soil physiology/metabolism.

How to establish new integrated scientific field for carbon control in ecosystem? It is requied 4 points as follow.
1) Monitoring of carbon combustion in ecosystem
2) Prediction of carbon combustion by climate change and human activity
3) Prediction of fragile ecosystem change by climate change
4) Establishment of technology for carbon storage in ecosystem

To avoid the destruction of these ecosystems, this fragile environment should be maintained by minimizing chemical inputs. To develop this new bio-production system, first it is important to know how native plants have developed the ability to adapt to adverse soil conditions. We should balance traditional and new sustainable technology (agro-forestry, mix cropping, micro-organisms symbiosis, natural pesticides or herbicides, and so on) for sustainable land management. We will try to implement these programs by involving local communities using the “inhabitant forest” concept.

To assess new integrated scientific field for carbon control in ecosystem, we open **Sapporo Affiliate Office of Global Land Project** proposed by Hokkaido University, Sapporo, Japan, which start from this year. Hokkaido University proposes “Sapporo Affiliate Office of Global Land Project” (hereafter, Sapporo Office) to affiliate with Global Land Project (GLP), a new joint core project of IGBP and IHDP. Sapporo Office is expected to facilitate synthesis and integration of individual research activities on land system change carried out around East Asian region. This

office takes part of the Hokkaido University Institute for Sustainable Development (HUISD), and is comprised of the **Sustainable Governance Project (SGP) of Hokkaido University**.

Purpose

Sapporo Office contributes to GLP through the following functions:

1) Facilitation of existing/ongoing research activities,
2) Interlinking international and regional/national activities,
3) Coordination of workshops and training courses, and
4) Synthesis and integration of research networks,

in collaboration with SSC-GLP, and IPO-GLP established in Colorado.

Thematic/regional foci

Possible target research themes and regional interests (and liaison with other projects) are:

1) Northern systems affected by global warming (NEESPI),
2) Freshwater linkage, and watershed-scale processes,
3) Modeling ecological-human processes at regional scales (AIMES, GCP),
4) Southeast Asia restoration and sustainable management (MAIRS, DIWPA), and
5) Training, education and capacity building in Southeast Asia (START).

The themes need to be specified and accepted by SSC-GLP.

Organization

Sapporo Office is constituted of following staffs:

1) Director (full-time): a scientist who can make a network,
2) Deputy director (part-time): natural scientist if director is social scientist, and *vice versa*, maybe nominated from Hokkaido University staffs,
3) Secretary (full-time): fluent in English,
4) IT coordinator (part-time): web construction and supporting telecommunication.

Director is jointly selected by GLP and SGP Committee of Hokkaido University through public advertisement. He or she is expected to contribute to university education with visiting professorship, based on international recognition of global environmental change.

Budget

Main financial support for Sapporo Office comes from Hokkaido University, in relation to HUISD and SGP, together with possible additional support from other agencies such as JICA (for capacity building in Southeast Asia). Hokkaido University provides the budget for one full-time director; one full-time secretary; additional functions and staffs are covered by appointed staffs of SGP. The office infrastructure and travel costs (director's travel, invitation of meetings) are also from university budget.

Term

Five years from April 2006.