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CARBOPEAT

Carbon–Climate–Human Interactions in Tropical Peatlands: Vulnerabilities, Risks & Mitigation Measures

Specific Support Action (SSA)

Publishable Final Activity Report

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1. Project Execution

1.1 Summary Description of Project Objectives

The overall goal of the CARBOPEAT project has been to promote enhanced understanding and awareness of **Carbon-Climate-Human Interactions in Tropical Peatlands,** focusing on the vulnerabilities of and risks to the tropical peatland carbon pool and mitigation measures to reduce GHG emissions, through 'wise use' of renewable natural resources.

This overall goal comprised five objectives:

1. To integrate and synthesize information and knowledge derived from EU INCO projects on tropical peatland (EUTROP, STRAPEAT AND RESTORPEAT) with those of other research teams working in related areas of expertise to identify key issues and critical gaps in the understanding of carbon-climate-human interactions in tropical peatlands, determine implications for policy, and formulate guidelines for optimizing the tropical peat carbon store that can be understood readily by policy makers and decision takers in EU and DC government agencies.
2. To establish an international expert network of key stakeholders involved in scientific research, data assessment and modelling, carbon accounting and policy formulation to address global and regional issues of tropical peatland carbon balance, GHG emissions and human impacts upon these within the overall context of sustainable wise use of renewable natural resources.
3. To facilitate access to knowledge and expertise on the carbon-climate-human interactions of tropical peatlands; integrate with similar information on boreal and temperate peatlands; produce policy guidance targeted at international conventions, industry and Governments.
4. To investigate potential carbon offset and trading mechanisms with respect to tropical peatlands and design reporting and monitoring guidelines for carbon stocks in tropical peatlands.
5. To establish platforms for information dissemination and the preparation of implementation strategies and policy recommendations to the benefit of industry, EC and DC Government agencies and other stakeholders.

1.2 Contractors

Partic. Role	Partic. No.	Participant name	Participant short name	Country
CO	1	University of Leicester	UNILEI	UK
	2	University of Gadjah Mada	UGM	Indonesia
	3	University Sarawak Malaysia	UNIMAS	Malaysia
	4	Alterra, University of Wageningen	ALTERRA	Netherlands
	5	University of Helsinki	UNIHEL	Finland
	6	University of Nottingham	UNOTT	UK
	7	University of Can Tho	UNICAN	Vietnam

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Project Web Site

http://www.geog.le.ac.uk/carbopeat/index.html or www.carbopeat.org

1.3 Project Execution

The overall goal of the CARBOPEAT project has been to promote enhanced understanding and awareness of **Carbon-Climate-Human Interactions in Tropical Peatlands,** focusing on the vulnerabilities of and risks to the tropical peatland carbon pool and mitigation measures to reduce GHG emissions, through ‘wise use’ of renewable natural resources.

This overall goal comprises five objectives. These are itemized below with additional comments on the project end results and their relation to the current state-of-the-art.

Objective 1: **To integrate and synthesize information and knowledge, identify key issues and critical gaps in understanding, analyse implications for policy, and formulate guidelines for optimizing the tropical peat carbon store that can be understood readily by policy makers and decision takers.**

Results Achieved with Relation to Objectives and State-of-the-Art: Five project Working Groups (WGs) addressed the main issues affecting carbon-climate-human interactions in tropical peatlands. The principal tasks of the WGs were to prepare Working Papers and Technical Reports containing the most up to date information and assess its importance and relevance to stakeholder groups. These documents present a comprehensive synthesis of current state of knowledge and their conclusions and recommendations have contributed to policy formulation on climate change and biofuels feedstock cultivation. Further cutting edge research priorities have been identified while dissemination and outreach activities will continue beyond the period of activities funded by the EU.

Notable project actions and dissemination outputs under this objective are:

- Production of CARBOPEAT **Technical Report 1** on the size and location of tropical peat carbon pools and implications for land management.

Technical Report 1 provides a detailed assessment of the information available on tropical peatland area, volume and carbon content in order to provide best estimates ranges of variation. Accurate inventory of the tropical peatland resource is essential in order to (a) determine the pre-disturbance carbon pool, (b) estimate the transfers of peat-derived greenhouse gases to the atmosphere resulting from recent, rapid changes in land use and (c) predict likely future consequences under the influence of climate change. Determining the current role of tropical peatland in the carbon cycle requires knowledge of the area of tropical peatland and its thickness from which an estimate can be made of volume and carbon store.

The global tropical peatland area is 368,501 km^2 (11% of global peatland area); of this 252,229 km^2 (68.4%) is in Southeast Asia. Within Southeast Asia, Indonesia has the largest area (206,950 km^2, 56.2% of the total resource), followed by Malaysia (25,000 km^2, 6.8%) and Papua New Guinea (16,971 km^2, 4.6%) (Figure 1).

The global tropical peatland carbon pool is estimated to be 65.2 Gt[1]. The largest share is located in Southeast Asia (61.4 Gt, 94.2%), followed by South America (2.6 Gt, 4.0%), Africa (0.8 Gt, 1.3%), Central America and the Caribbean (0.3 Gt, 0.4%) and Asia (other) and the Pacific region (0.05 Gt, 0.1% combined). Within Southeast Asia, Indonesia holds the largest share of the tropical peatland

[1] Gt = Gigatonne = billion tonnes = tonnes x 10^9 = grammes x 10^{15}

carbon pool (52.2 Gt, 80%), followed by Malaysia (8.8 Gt, 13.5%). On this basis, tropical peat contains 14% of the global peat carbon store and ~4% of the global soil carbon pool.

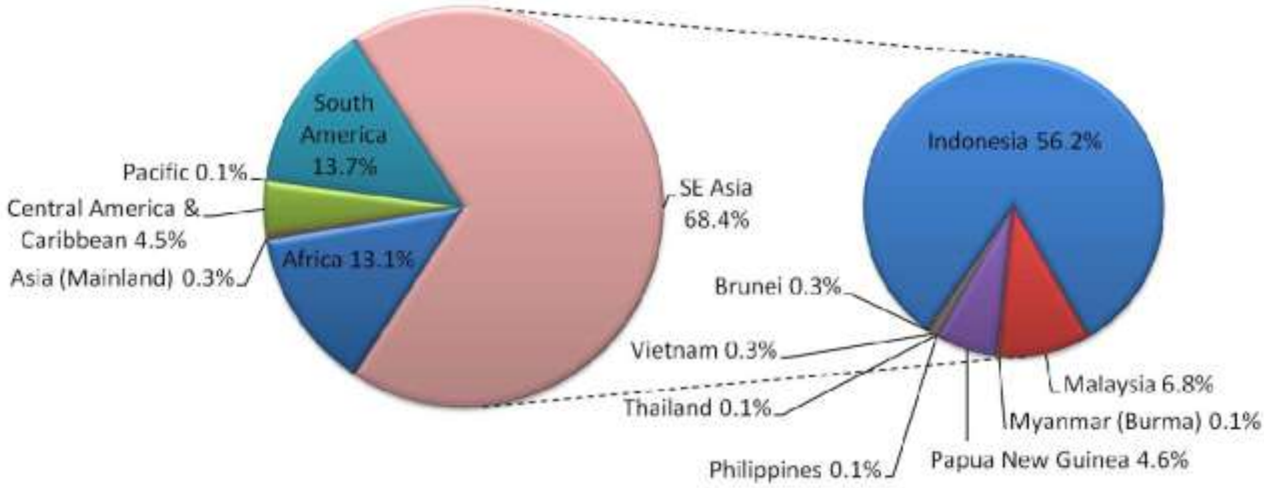

Figure 1: Distribution of tropical peatland based on best estimate values of area – a key result from Working Group 1

These data stress the prominent role played by Southeast Asian peatland in terrestrial carbon storage. This region is experiencing rapid land use change and, as a result, peatland is being converted from a carbon sink to a carbon source. It is estimated that the pre-disturbance peatland sink in Southeast Asia was ~20 Mt C yr^{-1} (~20% of the global pre-disturbance peatland sink) but, through recent land use change and fire, this function has been severely impaired, with an average annual loss of ~468 Mt C (1.7 Gt CO_2), equivalent to ~6% of global emissions from fossil fuels. These losses derive from reduction in peat carbon sequestration, increase in peat oxidation (a consequence of drainage) and fire.

The data presented in this report provide a baseline for assessing national and regional carbon stocks, for scaling up greenhouse gas flux estimates from tropical peatlands and for improved peatland management planning.

- Production of CARBOPEAT **Technical Report 2** on tropical peat carbon gas interactions.

This report focuses on the impact of land use change on tropical peatland carbon gas emissions (Figure 2). Data on greenhouse gas exchange between tropical peat and the atmosphere are presented and reviewed, and threshold factors influencing carbon flux processes in different land uses, excluding fire, are assessed.

Tropical peat swamp forest is one of the most efficient terrestrial carbon-sequestering ecosystems. The best carbon storing capacity is created by a combination of flood tolerant vegetation that can provide a constant supply of organic matter and a waterlogged, anoxic environment in which decomposition is slow. In recent decades, large areas of peatland in Southeast Asia have been developed for agriculture, plantation crops and human settlement. These changes necessitate removal of peat swamp forest, followed by drainage. In managed, drained peatland, the immediate consequence of water table draw down is an enhanced rate of peat decomposition as a result of oxidation leading to increased emissions of the greenhouse gas carbon dioxide (CO_2).

Review of data from a wide range of sources shows that the relationship between water table depth and peat surface carbon dioxide (CO_2) emissions from tropical peatland under different land uses has been mostly misunderstood. Previous conclusions that CO_2 emission ─ water table depth dependence was linear are incorrect and, in fact, emissions change non-linearly as drainage depth increases below the surface. Most of the change in the rate of CO_2 emission takes place near to the peat surface at shallow water table depths of less than 40 cm. Emission rates increase as water tables fall to a depth of around 80 cm in all land uses where they reach a maximum, level out and thereafter their estimation becomes difficult owing to a lack of field data in the literature.

Discussion of the current role of tropical peatlands in regional and global climate change processes is based mostly on circumstantial and secondary evidence, largely because total ecosystem carbon balance studies are very few and unsatisfactory. The role of above ground vegetation in sequestering CO_2 is largely unknown on tropical peatland under all land uses and the extrapolation of peat surface CO_2 emissions as surrogates for peat (eco)system carbon balance is highly questionable except from completely bare (unvegetated) peat. In addition, peat surface carbon flux data are spatially very fragmented and have not usually been collected over entire diurnal or seasonal cycles. Interpretation of the impact of biophysical factors of tropical peat on tropical peat carbon dynamics is very difficult because of variations in environmental conditions (especially peat hydrology), peat and vegetation cover that are not collected systematically or reported adequately in studies.

There is an urgent need to obtain peatland (eco)system level carbon balance estimates based both on gaseous fluxes and biomass studies, and to identify the influencing factors and determine their impact. It is important to separate more accurately CO_2 emissions from root respiration and organic matter decomposition from peat under different land use types and compare emissions immediately following land use change and drainage with those years afterwards.

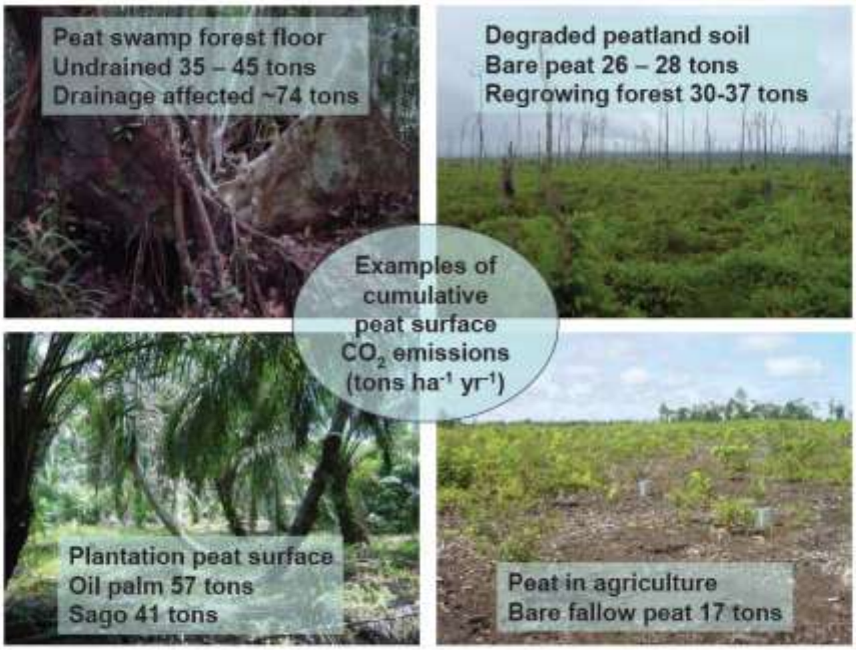

Figure 2: Examples of cumulative peat surface CO_2 emissions under various land uses – a key result from Working Group 2

- Production of CARBOPEAT **Technical Report 3** on assessment of risks to, and vulnerabilities of, tropical peatland carbon pools – mitigation and restoration strategies.

Tropical peatlands are important reservoirs of biodiversity, water and carbon. Their peat carbon pool is under threat from land use change, that requires drainage of the originally water saturated peat, and fire. Peat swamps influence the hydrology of entire catchments and excessive drainage destroys their 'sponge' effect causing loss of water reservoir function. Degradation of peat swamp forest reduces the ability of the ecosystem to regulate rainfall and water is flushed more quickly into rivers, causing flooding downstream. Despite the tropical wet climate, peat swamps suffer from water shortage during dry periods and they become prone to fire.

The sequence of events in peatland conversion is as follows:
deforestation → drainage → lowered water table → peat subsidence → carbon loss

Drainage of tropical peatland causes changes in the biological, chemical and physical characteristics of the peat that lead to loss of surface peat, a process known as subsidence (Figure 3). Peat subsidence is an irreversible process that commences as soon as peatland is drained and the continued lowering of the surface can be stopped only by complete water re-saturation of the peat. Peat subsidence can be partitioned into an early, rapid consolidation phase and an ongoing, oxidation (leading to CO_2 emissions) and shrinkage phase. Data from Malaysia show that there was initial, rapid subsidence of 15 cm per year in the first 7 years following drainage, which decreased to 5 cm per year between 8 and 20 years, reducing to 2 cm per year subsequently.

The subsidence rate is related to the depth of the water table level below the peat surface. This relationship can be used to estimate subsidence and CO_2 emission rates under the optimal water table levels required by different land uses. For example, the rate of subsidence under sago cultivation, with an optimum water table level of 40 cm, will be two-thirds that of peat under oil palm cultivation with an optimum water table level of 60 cm. By combining subsidence rates with the thickness of peat, the time it will take for all of the peat in a particular location to disappear can be predicted.

Fire susceptibility on tropical peatland is also related to water table level, increasing following drainage and in markedly dry seasons. Research shows that peat fire risk becomes extremely high when the water table falls below 80 cm. Appropriate water management can reduce carbon losses caused by both drainage and fire (Figure 4). Only rewetting of the peat restores its natural resource functions, decreases peat oxidation and CO_2 emissions and reduces fire risk.

Figure 3: Unsuccessful conversion of peat swamp forest (right) to agricultural land (left) in the former Mega Rice Project area in Central Kalimantan, Indonesia

Figure 4: Peatland water control structures using a movable crest to adjust overflow

- Production of CARBOPEAT **Technical Report 4** on carbon offset and trading mechanisms for tropical peatland

There has been much interest recently in the potential of carbon payment schemes to promote forest restoration and these could be a source of additional funding for tropical peatland restoration. Peat rehabilitation and fire management has potential to generate carbon revenues (from reduced emissions) in the region of USD 50-100 million per year that could be shared between government and local communities but it remains to be seen whether or not carbon credits from tropical peat forests can be traded in significant measure in the near future. The three schemes discussed below may offer the greatest potential for carbon payments on tropical peatlands and could provide important sources of funding for peatland restoration, but strong government support is required to establish and develop pilot projects to test these different mechanisms.

'Avoided deforestation' (AD) schemes in the voluntary carbon markets sector and newer 'Reducing Emissions from Deforestation and Forest Degradation' (REDD) initiatives both offer incentives for protecting carbon stocks in natural forests and may also offer pro-poor benefits if suitably targeted. REDD could be an important mechanism for maintaining carbon stocks in tropical peat swamp forests and degraded peatlands by preventing further emissions from drainage and fire, but many potential investors still regard REDD schemes as too risky because of the difficulties of controlling leakage and demonstrating additionality. Carbon credit payments under REDD require the identification of the size of the carbon store in question and calculations of how much of it will be emitted under a 'business as usual' scenario and how much will be saved under REDD.

Alternative mechanisms for funding peatland restoration include 'Payment for Ecological Services' (PES) initiatives, which aim to compensate local communities for protecting environmental services such as carbon sequestration/storage, biodiversity conservation and watershed protection (Figure 5). PES initiatives were developed on the grounds that forest conservation is likely to be more successful if local people see economic opportunities in protecting rather than destroying forests. Such schemes are particularly relevant for tropical peatlands as these ecosystems act as important global carbon stores. PES schemes are based on direct, conditional payments to local land users for taking measures to promote ecosystem conservation and restoration. They can address rural poverty by offering alternative income sources (e.g. forest service payments) or indirect benefits (training, tenure security) to communities that want to be involved in forest or watershed protection. Investors can come from a wide range of sources such as EU electricity suppliers paying for carbon sequestration in the tropics via reforestation projects, conservation donors paying local communities to create wildlife corridors and reserves, or downstream water users paying upstream farmers for watershed protection services.

In light of the limitations and uncertainty associated with PES and REDD, another source of funding that could be tailored more specifically to tropical peat restoration and the provision of alternative income sources for local communities is the 'BioRights' approach used by Wetlands International.

This involves establishing business contracts and providing micro-credit for sustainable development in exchange for the rehabilitation or protection of globally important biodiversity including the protection of remaining peat swamp forests or the rehabilitation of degraded peatlands. Members of the 'global community' (represented by an NGO or bank) formulate business contracts that provide micro-credit funding while a local partner (stakeholder group or local community) delivers a mutually agreed environmental service. Part of the funding will need to go to other stakeholders such as government agencies that will regulate, monitor and manage the protected areas.

If carbon projects are to succeed, they must 'not only provide environmental gains, but also provide economic and social benefits to local stakeholders'. As REDD is not inherently pro-poor, the way in which payments will actually be distributed (which is yet to be decided) will determine its impacts on poor communities. To maximize likely success, REDD schemes need to recognize customary rights both as part of a pro-poor approach and also as a means of reducing conflicts that might result in fire, illegal logging, illegal encroachments, etc. It would make sense, therefore, to embed avoided carbon emissions projects in regional carbon protection master plans that take account of customary rights as well as other existing land designation systems.

Figure 5: Dr Suwido Limin of CIMTROP, University of Palangkaraya in Central Kalimantan explains his 'Buy a Living Tree' (BLT) programme to a group of international delegates attending the pre-symposium field excursion in August 2007. The BLT scheme provides local small-holder farmers with a financial incentive to plant and provide after-care for native peat swamp forest tree species planted on degraded peatland

- Production of CARBOPEAT **Technical Report 5** on policy guidance on tropical peatland carbon-climate-human interactions

For global concerns regarding carbon emissions to result in sustained action by resource poor peatland dependent communities, significant economic incentives are needed. Concern about climate change has generated much interest in reducing greenhouse gas emissions through the prevention of deforestation and land degradation. It has also helped to identify gaps in existing scientific knowledge about tropical peatland carbon budgets (under different land uses and over long temporal horizons) and highlighted the need for additional data on when and under what conditions different peatland ecosystems act as carbon sources or sinks. Detailed studies need to be carried out on how biomass changes and crop composition affect hydrology and soil structure and impact upon the peat carbon store as well as on the decomposition and subsidence that occur during development of tropical peatland.

For tropical peatland restoration initiatives to be successful ‘on the ground’, the involvement of local communities is essential given their high level of dependence on these resources and their ability to sabotage restoration efforts that don’t reflect their interests. This is no easy task as the diversity of requirements that characterise most local communities undermines simplistic assumptions about involvement in and capacity for natural resource management.

Mechanisms such as PES (Payment for Ecological Services), REDD (Reduced Emissions from Deforestation and Degradation), and Biorights offer important opportunities for tropical peatland restoration, but they have to be highly flexible and responsive to local needs if they are to offer pro-poor benefits as well as reduced CO_2 emissions. Scientific knowledge about reducing greenhouse gas emissions from tropical peatlands must be combined with participatory development projects that are flexible enough to work around existing local political structures and socio-cultural norms and provide long term economic benefits to local people.

New institutional finance structures are needed to manage the funding of these emerging carbon markets and there must be effective governance involving a high degree of transparency, monitoring and auditing to ensure that funding is channeled to local stakeholders**.** A halt to further deforestation could be a first step in countering peatland degradation and buying time to maximise carbon funding opportunities and would show a strong degree of political will if part of a longer-term strategy of land use planning.

Figure 6: Participatory approaches, for example workshops with local communities, are an essential part of knowledge exchange and transfer on peatland management

Objective 2: To establish an international expert network (IEN) of key actors involved in scientific research, data modelling, carbon accounting and policy formulation to address global and regional issues of tropical peatland carbon balance, GHG emissions and human impacts upon these within the overall context of sustainable wise use.

Results Achieved with Relation to Objectives and State-of-the-Art: For the first time, the CARBOPEAT project brought together a comprehensive group of tropical peatland stakeholders. Through membership of the IEN and/or inclusion on the project mailing list and/or participation in project symposia, workshops or other meetings, all participants received updates on current state of knowledge and were informed about project outputs and their land management and policy relevance.

Notable project actions and dissemination outputs under this objective have included:

- Establishment of an interactive **project web site** (www.carbopeat) to: (i) publicise the project and disseminate its work and recommendations, (ii) engage with the peatland and carbon research, management, industry and policy communities; (iii) interface with the International Expert Network; (iv) disseminate other peatland-related information.

The web site has several pages devoted to different aspects of carbon-climate-human interactions on tropical peatland, including (a) background to and information on the CARBOPEAT Project, (b) news items of interest and relevance to tropical peatland in general, (c) the various publications issued by the project and (d) a learning centre containing a range of useful tools for education, information, publicity and research on tropical peatlands.

- Nine newsletters were published during the 27 months of the CARBOPEAT Projects containing information on the partners and the contributions they made towards the Working Groups and dissemination activities of the Project.
- Six short information leaflets aimed at the non-peatland specialist and general public were produced on topics of importance including background to tropical peatland, biodiversity, carbon flux and storage and vulnerability to human impacts.
- Symposia and Workshop presentations, proceedings, publications and statements: the presentations given by participants at the two Major Events in Yogyakarta, Indonesia (August 2007), Tullamore, Ireland (June 2008) and Kuching, Malaysia (August 2008) have been posted on the web site as have the proceedings of the first two. In addition, there is the statement agreed by participants at the Yogyakarta meeting and a compendium of carbon-climate-human interaction papers presented at the Tullamore meeting.

- Three Major Events (International Symposia and Workshops) were held during the Project in order to discuss present, discuss and disseminate information related to carbon-climate-human interactions on tropical peatland:-
    - The first Major Event was held in Yogyakarta, Indonesia in August 2007 in partnership with Gadjah Mada University, Indonesia and the Indonesian Peat Association. The title of this event was *Carbon-Climate-Human Interactions on Tropical Peatland: Carbon Pools, Fire, Mitigation, Restoration and Wise Use.* It was attended by over 250 participants from 15 countries; 59 papers and posters were presented and these have been published on the Project Web Site. This meeting was preceded by a field excursion to Central Kalimantan, Indonesia where 50 participants inspected pristine tropical peatland, fire damaged peatland and peatland that had been damaged in the course of inappropriate development for agriculture. A post-conference field excursion was held to visit peatland under plantation in the Kampar District of Sumatra in Riau Province.
    - The second major event was held in conjunction with the 13th International Peat Congress in Tullamore, Ireland in June 2008. More than 500 participants from more than 50 countries attended this quadrennial meeting at which the CARBOPEAT

Project organized a special session on tropical peatland consisting of 26 papers and 7 posters. The proceedings of this congress are available on the web site of the International Peat Society (www.peatsociety.fi) while a compendium of papers and posters relevant to carbon-climate-human interactions on tropical peatland are published in book format on the CARBOPEAT web site.

- The third and final major event was held in Kuching, Sarawak, Malaysia in August 2008 with a special focus on policy makers in Southeast Asia. The title of this meeting was *'Peatland Development: Wise Use and Impact Management.* This meeting was attended by more than 150 participants from 15 countries; 50 oral and 15 poster presentations were made and these are available on the Project web site.

Objective 3: To facilitate access to knowledge and expertise on the carbon-climate-human interactions of tropical peatlands; integrate with similar information on boreal and temperate peatlands; produce policy guidance targeted at international conventions, industry and Governments.

Results Achieved with Relation to Objectives and State-of-the-Art: Both direct and indirect project activities enabled CARBOPEAT partners to disseminate current state of knowledge on tropical peatlands. This included participation in discussion meetings on carbon emission from oil palm development on tropical peatlands (Figure 7); pulpwood plantation development on tropical peatlands; the pulp and paper industry and the publishing industry with regard to sourcing paper from sustainable producers; private carbon offset proposals; the role of peatland fires in the global carbon cycle; the implications of REDD/Kyoto Protocol negotiations for tropical peatlands; REDD demonstration projects on tropical peatlands; the role of improved water management for plantations on tropical peatland; the role of wise use management principles in land use planning for degraded tropical peatlands; and the agricultural sector (both in DCs and the EU).

Figure 7: Inter-agency dialogue focusing specifically on the future direction of peat research in Malaysia in general and Sarawak in particular was held at Universiti Malaysia Sarawak (UNIMAS) in July 2008.

Objective 4: To investigate potential carbon offset and trading mechanisms with respect to tropical peatlands and design reporting and monitoring guidelines for carbon stocks in tropical peatlands.

Results Achieved with Relation to Objectives and State-of-the-Art: This is an area that CARBOPEAT partners rigorously pursued. Several meetings were organized, as a consequence of which four of the CARBOPEAT partners became involved in developing state-of-the-art methodologies for carbon trading. A proposal for carbon trading to conserve tropical peatland carbon stocks under the CDM (Clean Development Mechanism) of the UNFCCC is now being assessed by the CDM Board. Two of the partners have also been involved in designing a REDD-demonstration project on tropical peatland for the Australian Government and two of the partners were consulted on a VCS (Voluntary Carbon Standard) methodology for tropical peat swamp forest. All of these activities have contributed to a significantly raised profile for tropical peatlands in carbon offsetting and trading schemes.

Objective 5: To establish platforms for information dissemination and the preparation of implementation strategies and policy recommendations to the benefit of industry, EC and DC Government agencies and other stakeholders.

Results Achieved with Relation to Objectives and State-of-the-Art: The CARBOPEAT project held several stakeholder meetings, in Vietnam (Figure 8), Indonesia and Malaysia, during Reporting Period 1. These provided opportunities to disseminate and discuss the most up to date knowledge on tropical peatlands. Further meetings were held during Reporting Period 2, in particular in Kuching in conjunction with Major Event 3 and in Vietnam. As a result of a meeting of around 150 stakeholders allied to Major Event 1 in Yogyakarta in August 2007 a major statement on the importance of tropical peatland in carbon-climate-human interactions issues and guidance for inclusion in national and international policies was issued (see Appendix).

Figure 8: Stakeholder workshop organised by University of Can Tho, Vietnam. This partner organised a number of local workshops addressing issues associated with peat and acid sulphate soil management in the Mekong delta

2. Dissemination and Use

This section provides a summary of the publishable results arising to date from the CARBOPEAT project. Further publications and other project outputs are currently in preparation.

- Chapter on tropical peatland fires in SE Asia contributed to a book on tropical fire ecology: Page, S.E., Hoscilo, A., Langner, A., Tansey, K.J., Siegert, F., Limin, S. and Rieley, J.O. (2009) Chapter 9: Tropical peatland fires in Southeast Asia. In: Cochrane, M.A. (ed) *Tropical Fire Ecology: Climate Change, Land Use and Ecosystem Dynamics*. Springer-Praxis, Heidelberg, Germany.

  Extensive tropical peatlands are located in the Malaysian and Indonesian lowlands, particularly in Borneo, Sumatra, West Papua and Peninsular Malaysia. In an undisturbed condition, these peatlands make a significant contribution to terrestrial carbon storage, both in terms of their aboveground biomass (peat swamp forest) and thick deposits of peat. Occasional forest fires, including peatland fires, have occurred in Southeast Asia over several millennia but, in recent years, they have become a more regular feature. The most severe fires have been linked with the El Niño phase of ENSO which causes extended periods of drought, particularly across the peatland areas of southern Sumatra and southern Kalimantan. During the last twenty years, rapid land use change, exacerbated by climatic variability, has led to an increase in fire frequency, as the remaining peat swamp forests come under pressure from increased illegal logging, development for plantations and agriculture-based settlement and, where economic development has failed, land abandonment. A case study of fire occurrence in Borneo illustrates that peat swamp forests are much more prone to fire than any other forest type, largely as a result of the high pressure being put on these last remaining forested lands. From studies in Central Kalimantan (southern Borneo), we demonstrate the relationships between peat drainage, vegetation change and increased fire frequency, including the role that peat combustion and subsidence play in an increased incidence of surface flooding. Tropical peatland fires, and the changes in vegetation that they bring about, have significant impacts on the atmosphere, the carbon cycle and various ecosystem services; they also cause wide-ranging social and economic impacts. Fires on peatlands usually affect both the surface vegetation and the underlying peat layer and, as a result, they release much larger amounts of CO_2 into the atmosphere than forest fires on mineral soils. In 1997, peatland fires in Indonesia resulted in the release of between 0.81 and 2.57 Gt of carbon into the atmosphere, equivalent to 13-40% of mean annual global carbon emissions from fossil fuels, and over the last ten years a conservative estimate of total carbon emissions from peatland fires in Southeast Asia is of the order of 2 to 3 Gt. Future climate changes may place further pressure on the tropical peatland ecosystem and are likely to lead to enhanced carbon emissions from both peat degradation and fire.

- Chapter on tropical peatlands and climate change contributed to a book on peatlands and climate change: Rieley, J.O., Wüst, R.A.J., Jauhiainen, J., Page, S.E., Wösten, H., Hooijer, A., Siegert, F., Limin, S., Vasander, H. and Stahlhut, M. (2008) Chapter 6: Tropical peatlands: Carbon stores, carbon gas emissions and contribution to climate change processes. In: Strack, M. (ed) *Peatlands and Climate Change*. International Peat Society, pp. 129-162.

  Tropical peatland acts as both a sink of carbon and a source depending on seasonal changes in precipitation, temperature, type of vegetation cover and land use. The onset and formation of peatlands in Southeast Asia range from the late Pleistocene to the Holocene, although most originated during the middle to late Holocene. In the Sabangau peatland of Central Kalimantan peat accumulation rate in the Early Holocene ranged from 0.60 to 2.55 mm yr^{-1}; the average rate of carbon accumulation was 92 g C m^{-2} yr^{-1}, with a maximum of 131 g C m^{-2} yr^{-1}. Current tropical peat accumulation rates range from 0.59 – 1.45 t ha^{-1} yr^{-1}, exceeding the most rapid rates for boreal, temperate and subarctic ombrotrophic bogs. Indonesia's peatlands (20.074 Mha) have a potential, pre-disturbance peatland carbon sink of 20.28 Mt yr^{-1} while the global tropical peatlands as a whole (37.80 Mha) could absorb 38.18 Mt yr^{-1}, which is equivalent to about 58% of temperate, boreal and subarctic peatlands (66.2 Mt yr^{-1}). The estimated annual CO_2 flux in undrained, selectively logged forest in Central Kalimantan under various hydrological conditions is in the range 953±86 – 1061±83 g C m^{-2} yr^{-1} (3497.5±315.6 – 3893.9±304.6 g CO_2 m^{-2} yr^{-1}), which is considerably more than the 60-200 g C m^{-2} yr^{-1} (220-7334 g CO_2 m^{-2} yr^{-1}) from boreal *Sphagnum*-dominated ombrotrophic bogs. CH_4 emissions from the forested peat surface are between 0.96 and 8.41 g CH_4-C m^{-2} yr^{-1}, which are lower than those from boreal *Sphagnum*-dominated bogs of 2 to 15 g CH_4-C m^{-2} yr^{-1}. Comparative studies show that CO_2 emissions from drained forest and recovering sites (undergoing succession to secondary forest) are slightly higher than those from undrained forest probably owing to higher autotrophic respiration from tree roots and enhanced peat oxidation as a result of drainage. Annual CO_2 emissions from a drained agricultural site are considerably lower than at all other sites (526 g CO_2 m^{-2} yr^{-1}) because there are no trees to provide a supply of litter to peat surface decomposers; the replacement vegetation root biomass is small and produces much less respiratory CO_2 than rain forest trees. Net peatland carbon flux is determined mainly by the net balance between CO_2 uptake in photosynthesis and C-release by ecosystem respiration but there is a lack of accurate data on the amount of CO_2 sequestered by green plants in photosynthesis. The large amount of CO_2 emitted from the peat surface in undrained peat swamp forest is likely to be mostly or completely reabsorbed by the forest vegetation making it either CO_2 neutral or, if the peatland is accumulating peat, the ecosystem must be CO_2 negative. Annual methane emissions are highest in drainage affected forest and recovering forest sites both of which are subjected to periodical waterlogging and receive inputs of easily decomposable litter from the canopy. Peak CH_4 emissions occur when the water table is near or above the peat surface. Uncultivated agricultural peatland has a CH_4 emission of almost zero at all peat water table depths owing to the permanently low water table following drainage to grow crops. The global warming potential (GWP) of methane emitted from tropical peat is of minor importance compared to that of the CO_2 emissions and represents only 0.8 – 0.9% of the corresponding CO_2 emissions (3892 – 3493 g CO_2 m^{-2} yr^{-1}) from the ground in undrained forest. The carbon stores in Indonesian peatland, SE Asian peatlands and tropical peatlands globally is in the order of 45, 58 and 84 Gt, respectively. Deforestation, drainage and agriculture on tropical peatland are converting large areas from active carbon sinks to carbon sources. The total current CO_2 emissions from tropical peatland of approximately 2000 Mt yr^{-1} equal to almost 8% of global emissions from fossil fuel burning. Emissions are likely to increase every year for the first decades after 2000. As the deeper peat deposits will take much longer to be depleted, significant CO_2 emission will continue beyond 2100. It is essential that future land use of tropical peatland incorporates the principles and practices of sustainable 'wise use', especially with respect to hydrology, water and carbon management.

- Paper on ecosystem restoration on tropical peatlands for the journal Ecosystems: Page, S.E., Hoscilo, A., Jauhiainen, J. et al. (2009) Ecological restoration of tropical peatlands in Southeast Asia. Ecosystems 10.1007/s10021-008-9216-2

Studies of restoration ecology are well established for northern peatlands, but at an early stage for tropical peatlands. Extensive peatland areas in Southeast Asia have been degraded through deforestation, drainage and fire, leading to on- and off-site environmental and socio-economic impacts of local to global significance. In order to address these problems, landscape-scale restoration measures are urgently required. This paper reviews and illustrates, using information from on-going trials in Kalimantan, Indonesia, the current state of knowledge pertaining to: (i) land cover dynamics of degraded peatlands; (ii) vegetation rehabilitation, (iii) restoration of hydrology, (iv) rehabilitation of carbon sequestration and storage, and (v) promotion of sustainable livelihoods for local communities. For a 4,500 km^2 study site in Central Kalimantan, Indonesia we show a 78% reduction in forest cover between 1973 and 2003 and demonstrate that fire, exacerbated by drainage, is the principal driver of land use change. Progressive vegetation succession follows infrequent, low intensity fires, but repeated and high intensity fires result in retrogressive succession towards non-forest communities. Re-wetting the peat is an important key to vegetation restoration and protection of remaining peat carbon stocks. The effectiveness of hydrological restoration is discussed and likely impacts on greenhouse gas emissions evaluated. Initial results indicate that raised water levels have limited short-term impact on reducing CO_2 emissions, but could be critical in reducing fire risk. We conclude that successful restoration of degraded peatlands must be grounded in scientific knowledge, relevant to socio-economic circumstances, and should not proceed without consent and co-operation of local communities.

- Paper on relationship between MODIS hotspot data and burnt area on tropical peatlands for the Journal of Geophysical Research: Tansey, K., J. Beston, A. Hoscilo, S. E. Page, and C. U. Paredes Hernández (2008) Relationship between MODIS fire hot spot count and burned area in a degraded tropical peat swamp forest in Central Kalimantan, Indonesia. J. Geophys. Res., 113, D23112, doi:10.1029/2008JD010717.

  A number of spaceborne sensors observe radiant energy at thermal wavelengths. Thermal anomaly data, otherwise known as hotspot data, have been shown to be particularly correlated with the occurrence of active fires (a fire normally with a flaming component and/or smoldering component). Due to a lack of high quality burned area data, recent studies have used hotspot data as a proxy for burned area when calculating gas emissions or atmospheric pollutants as a result of biomass burning. We argue that the relationship between hotspot data and burned area is spatially variable and strongly dependent on the vegetation type and function. In this paper, we explore the relationship between hotspot data and burned area for a region of degraded and partially altered tropical peat swamp forest in southern Kalimantan, Indonesia. MODIS thermal anomaly (MOD14A1) data were used, alongside Disaster Monitoring Constellation (DMC) and Landsat TM data that were used to derive the burnt area, to calculate a figure indicating the average burned area per hotspot (A_R). Two different levels of hotspot detection confidence are examined, in order to ascertain which confidence levels best describe fires in a tropical peat swamp forest environment. Burn scars were best detected by utilizing all hotspot detection confidence levels. Results for the estimation of burnt area for each hotspot were found to vary between 12 and 16 ha. Omission errors are of the order of 60%; hotspot commission rates are of the order of 7%.

- Papers presented to the IPS conference (Major Event 2) Ireland, on a range of tropical peatland issues. Edited and published as a Carbopeat output – available at: http://www.geog.le.ac.uk/carbopeat/media/pdf/tullamorepapers/ipc_tropical_peat_special_session.pdf

- Papers presented to the Kuching tropical peatland conference (Major Event 3), on a range of tropical peatland issues; available at: http://www.geog.le.ac.uk/carbopeat/kuchingcontents.html

- Information leaflets on Introduction to Tropical Peatland, Tropical Peatlands & Carbon Storage, Tropical Peatlands & Carbon Gas Fluxes, Tropical Peatlands & Biodiversity in SE Asia, and Vulnerabilities of Tropical Peatlands; available at: http://www.geog.le.ac.uk/carbopeat/infleaflets.html

- Full edited papers from Major Event 1 (Yogyakarta, Indonesia) published and available via project website: http://www.geog.le.ac.uk/carbopeat/yogyaproc.html

- Report on the science of tropical peatlands written as a document for policy makers and published as part of the Plan for the Rehabilitation and Restoration of the Mega Rice Project area, Central Kalimantan: Rieley, J.O. and Page, S.E. (2008) The science of tropical peatlands and the Central Kalimantan peatland development area. Master Plan for the Conservation and Development of the Ex-Mega Rice Project Area in Central Kalimantan. Euroconsult Mott McDonald, The Netherlands. 64 pp. Available via project website at: http://www.geog.le.ac.uk/carbopeat/publications.html

- ALTERRA contributed to a policy brief: Verwer, C. van der Meer, P. and Nabuurs, G.J. (2008) 'Policy Brief. Oil Palm Cultivation on Malaysian Peatlands and its consequences for CO_2 emissions', Alterra: Wageningen. This report helped to develop bilateral co-operation between Malaysia and The Netherlands and is available via the project website at: http://www.geog.le.ac.uk/carbopeat/publications.html

- Paper on peat and water interrelationsips in Central Kalimantan published in the journal Catena: Wösten, J.H.M., Clymans, E., Page, S.E., Rieley, J.O., Limin, S.H., 2008. Peat – water interrelationships in a tropical peatland ecosystem in Southeast Asia. Catena 73, 212-224. Do1: 10.1016/j.catena.2007.07.010

  Interrelationships between peat and water were studied using a hydropedological modelling approach for adjacent relatively intact and degraded peatland in Central Kalimantan, Indonesia. Calculated groundwater levels for different years and for different months within a single year showed that these levels can drop deeper than the critical threshold of 40 cm below the peat surface whereas also flooding of more than 100 cm was calculated. Ideally, groundwater levels varied between 40 cm below and 100 cm above the peat surface. In the 1997 dry El Niño year, areas for which deep groundwater levels were calculated coincided with areas that were on fire as detected from radar images. The relatively intact peatland showed resilience towards disturbance of its hydrological integrity whereas the already degraded peatland remained susceptible to recurrent fires. Hydropedological modelling identified areas with good restoration potential based on predicted flooding depth and duration. Groundwater level prediction maps can be used in fire hazard warning systems as well as in land utilization and restoration planning. It is demonstrated that the combination of hydrology and pedology is essential for wise use of valuable but threatened tropical peatland ecosystems.

- Paper on GHG emissions from drained tropical peatland published in the journal Ecology: Jauhiainen, J., Limin, S., Silvennoinen, H. & Vasander, H. (2008). Carbon dioxide and methane fluxes in drainage affected tropical peat before and after hydrological restoration. Ecology 89(12), 2008, pp. 3503–3514

Present tropical peat deposits are the outcome of net carbon removal from the atmosphere and form one of the largest terrestrial organic carbon stores on the Earth. Reclamation of pristine tropical peatland areas in Southeast Asia increased strikingly during the last half of the 20th century. Drainage due to land-use change is one of the main driving factors accelerating carbon loss from the ecosystem. Dams were built in drainage-affected peatland area canals in Central Kalimantan, Indonesia, in order to evaluate major patterns in gaseous carbon dioxide and methane fluxes and in peat hydrology immediately before and after hydrologic restoration. The sites included peat swamp forest and deforested burned area, both affected by drainage for nearly 10 years. Higher annual minimum soil water table levels prevailed on both sites after restoration; the deforested site water table level prevailed considerably longer near the peat surface, and the forest water table level remained for a longer period in the topmost 30 cm peat profile after restoration. Forest soil gas fluxes were clearly higher in comparison to the deforested area. Cumulative forest floor CO_2 emissions (7305–7444 g $m^{-2}yr^{-1}$; 166.0–169.2 mol CO_2 $m^{-2}yr^{-1}$) and the deforested site CO_2 emissions (2781–2608 g $m^{-2}yr^{-1}$; 63.2–59.3 mol CO_2 $m^{-2}yr^{-1}$) did not markedly reflect the notably differing hydrological conditions the year before and after restoration. The forest floor was a weak CH_4 sink (0.208 to 0.368 g $m^{-2}yr^{-1}$; 13.0 to 22.9 mmol CH_4 $m^{-2}yr^{-1}$) and the deforested site a comparable CH_4 source (0.197–0.275 g $m^{-2}yr^{-1}$; 12.3–17.1 mmol CH_4 $m^{-2}yr^{-1}$) in the study period. In general, higher soil water table levels had a relatively small effect on the annual CH_4 emission budgets. In the two site types the gas flux response into hydrological conditions in degraded tropical peat can be attributed to differing CO_2 and CH_4 dynamics, peat physical characteristics, and vegetation.

- Paper on controls on carbon balance in tropical peatlands published in the journal Ecosystems: Hirano,T., Jauhiainen, J., Inoue, T. & Takahashi, H. (2008). Controls on the carbon balance of tropical peatlands. Ecosystems DOI: 10.1007/s10021-008-9209-1.

The carbon balance of tropical peatlands was investigated using measurements of gaseous fluxes of carbon dioxide (CO_2) and methane (CH_4) at several land-use types, including nondrained forest (NDF), drained forest (DF), drained regenerating forest (DRF) after clear cutting and agricultural land (AL) in Central Kalimantan, Indonesia. Soil greenhouse gas fluxes depended on land-use, water level (WL), microtopography, temperature and vegetation physiology, among which WL was the strongest driver. All sites were CH_4 sources on an annual basis and the emissions were higher in sites providing fresh litter deposition and water logged conditions. Soil CO_2 flux increased exponentially with soil temperature (T_s) even within an amplitude of 4–5_C. In the NDF soil CO_2 flux sharply decreased when WLs rose above -0.2 and 0.1 m for hollows and hummocks, respectively. The sharp decrease suggests that the contribution of surface soil respiration (RS) to total soil CO_2 flux is large. In the DF soil CO_2 flux increased as WL decreased below -0.7 m probably because the fast aerobic decomposition continued in lower peat. Such an increase in CO_2 flux at low WLs was also found at the stand level of the DF. Soil CO_2 flux showed diurnal variation with a peak in the daytime, which would be caused by the circadian rhythm of root respiration. Among the land-use types, annual soil CO_2 flux was the largest in the DRF and the smallest in the AL. Overall, the global warming potential (GWP) of CO_2 emissions in these land-use types was much larger than that of CH_4 fluxes.

- Paper presented at Seminar Nasional Pertanian Laha Rawa in Banjarbaru, Kapuas, August 2007: Ruly E. K. Kurniawan dan B. Radjagukguk Pengaruh Pemberian Bahan Amelioran Terhadap Serapan Hara Kalium(K) dan Kalsium(Ca) Tanaman Jagung Pada Tanah Gambut Ombrogen **(**the effect of ameliorant application for potassium (K) and calcium (Ca) uptake Corn on ombrogenous peat soil)

A glasshouse experiment was carried out to determine acidity factor and the effct of ameliorant application for the growth of plant on sapric ombrogenous peat soil, using corn (Zea mays,L) as the test plant. The peat soil, taken from the top 30 cm, originated from the Kalampangan Village (Eks Blok C Mega Rice Project), Pangkaraya, Central Kalimantan. The experiment was conducted using the complete randomized design (CRD) with three kinds of ameliorant, each applied at two levels. The ameliorant consisted of $CaCO_3$ at 6.5 and 8.5 ton/ha, volcanic ash at 0 and 40 ton/ha, and legume plant material at 10 and 20 ton/ha. A treatment without ameliorant application served as control. Basal fertilizer were applied to the soil in each pot. Each treatment had three replications. The method for analysis of K_{exc} and Ca_{exc} used were the extraction by 1 N NH_4OAc pH 4.8 (Radjagukguk et al.,2000), Total K and Ca concentration on plant extraction with HNO_3 and $HClO_4$ by wet digestion and Atomic Adsorption Spectrophotometer (Houba et al.,1995). Corn stage i.e 55 days from planting. The Result showed that $CaCO_3$ increased the pH, K_{exc}, Ca_{exc}, dry weight of plant tops and roots as wel as plant height, and increased K and Ca uptake in the plant. Volcanic ash increase the pH. K_{exc}, Ca_{exc}, dry weight of plant tops and roots as wel as plant height, and increased K and Ca uptake in the plant. Legume plant material increased pH, K_{exc} and Ca_{exc} and decreased dry weight of plant tops and roots, plant height and decreased K and Ca uptake in the plant. It was concluded that acidity factors in the ombrogenous peat soil with impeded plant growth were H^+ ion.

- Paper presented at Peat-ASEAN Workshop "Development of Effective Microbial Consortium Potent in Peat Modification", BPPT Jakarta, November 2008: Bostang Radjagukguk : Peat Soil for Sustainable Agriculture

Peatlands in Indonesia cover a total area of some 20 million hectares (52.4% of peatlands found in the tropical zone), or about 10 % of its total land area. These peatlands are considered to be potentially important for future expansion of cropland and, indeed, a sizable proportion has been put into cultivation. Realizing that agricultural utilization of peatland in developing countries of the tropics, including Indonesia, arises out of necessity, the challenge faced is how to reconcile the pressure for this sectoral development and the need to conserve the fragile ecosystem. The Indonesian lowland peatlands were formed mostly from forest vegetation, under water saturated condition, thus have a high wood content. The peat layers vary greatly in thickness, but dominantly greater than 200 cm. Physically they are characterized by a very low bulk density, a low bearing capacity, a high horizontal but low vertical hydraulic conductivity, and a high total porosity. Its water holding capacity is very high but tends to become hydrophobic when too dry. With land clearing and drainage, the peat soils undergo subsidence. Chemical fertility of the peat soils is generally very poor. The peat soils have low pH (range 3-4) and most essential plant nutrients are in deficient supply. Cation exchange capacity (CEC) of the peat soil is relatively high, on weight basis, C/N ratio is high, whereas exchangeable Al is relatively low. In the management of peatland for the cultivation of annual and perennial crops, the main physical constraint encountered is the low bearing capacity. Deficiency of macro- and micro-nutrients can be alleviated with fertilizer application. The application of ash, and biological management of the peat soil, need to be maximised to reduce or even avoid the use of lime which is costly. Appropriate water management and control through the construction of drainage/irrigation system constitutes a key factor in achieving successful plant cultivation on the peatland. Sustainable agriculture is one that is productive and profitable, conserves the natural resource base, and imposes minimal adverse impacts on the environment. The sustainability of an agricultural system can be assessed using biophysical indicators such as productivity, stability, resilience, and adaptability. In the case of tropical peatland, these indicators can be measured in terms of crop yield and quality, soil fertility and nutrient balance sheet, soil loss, greenhouse gas emission and water quality. Evidence from Indonesia (and also Malaysia) strongly indicates that certain agricultural systems on the tropical peatland are productive and profitable, and may indeed prove to be sustainable in the long term. The main challenges faced are related to conservation of the peat substrate and minimization of adverse impacts on the environment. It is strongly believed that, with proper planning and wise management, aided by development of appropriate technologies, the tropical peatland can be used sustainably for selected agricultural systems with the understanding that what needs to be conserved is its productive function, and not merely its physical form.

- Paper presented at the National Seminar on Rice held in Sukamandi, Indonesia: Bostang Radjagukguk. Prospek dan kendala pemanfaatan lahan gambut untuk tanaman pangan (*Prospects and problems of peatland utilization for food crops*).

  Peatlands in Indonesia cover a total area of some 20 million hectares, or about 10 % of its total land area. Increasing utilization of this resource arises out of necessity, in particular for the expansion of cropland. Up to 1983, over 1.3 million hectares of peatlands had been surveyed for the transmigration program and of these, some 531,000 hectares were considered suitable for agriculture development, a large portion of which had been opened for transmigration settlements.The cultivation of upland crops, in particular cash crops, is almost always attempted by local and transmigrant farmers on the peat soils. Crops widely grown are soybean, corn, upland rice, peanut, cassava and sweet potato, but their productivity is generally low. To obtain reasonable yields, application of macro- and micro-nutrient fertilizers and liming are commonly required. Paddy cropping is attempted by the transmigrant farmers on the peatlands in order to satisfy the need of the transmigrant family for this staple food commodity, and at the same time support the national food self-sufficiency program. Nonetheless, paddy cropping on the peat soils encounters various problems consisting of physical and chemical problems as well as those related to water management. The utilization of relatively thick peats (> 1m), in particular, for paddy cropping has to date been unsuccessful due to presence of constraints many of which have so far not been well understood. The key to successful utilization of the peatlands for paddy cropping appears to rest on proper water management and control, successful management of soil physical constraints, the alleviation of toxic substances and appropriate application of macro- and micro-nutrient fertilizers.

APPENDIX

INTERNATIONAL SYMPOSIUM AND WORKSHOP ON TROPICAL PEATLAND

| YOGYAKARTA, INDONESIA | 27-31 AUGUST 2007 |

Secretariat: Faculty of Agriculture, Gadjah Mada University, Bulaksumur, Yogyakarta 55281, Indonesia
Telp./Fax: +62 274 548814 Website: http://soil.faperta.ugm.ac.id/CT E-mail: tropeat_symposium@yahoo.com

STATEMENT

Issued by 150 participants of the

International
Symposium, Workshop and Seminar on Tropical Peatland,
Yogyakarta, Indonesia,
27 - 31 August 2007

"Carbon - Climate - Human Interactions - Carbon Pools, Fire, Mitigation, Restoration and Wise Use"

organized by

Department of Soil Science,
Faculty of Agriculture,
Gadjah Mada University,
Indonesia

in association with

Indonesian Peat Association

International Peat Society

BAPPENAS

On behalf of the

EU CARBOPEAT AND RESTORPEAT RESEARCH PARTNERSHIPS

YOGYAKARTA STATEMENT ON CARBON-CLIMATE-HUMAN INTERACTIONS ON TROPICAL PEATLANDS

Problems of fire, mitigation, restoration and wise use of tropical peatland were addressed at the **International Symposium and Workshop** on ***"Carbon-Climate-Human Interactions on Tropical Peatlands"*** held in **Yogyakarta, Indonesia on 27-29 August 2007**. These meetings were attended by over 200 participants from Indonesia, Malaysia and Vietnam and 13 other countries, including scientists, politicians, legislators, land managers, representatives of national and local government, NGOs and community groups, and the private sector. The symposium consisted of seven technical sessions, with 38 papers, dealing with the following important issues concerning tropical peatlands and peat:

1. Evolution, extent and natural resource functions;
2. Biodiversity and biological, chemical and physical characteristics;
3. Restoration and water management;
4. Carbon dynamics;
5. Socio-economics and land management;
6. Fire: detection, impacts, awareness and control;
7. Carbon payments, avoided deforestation and cultivation of plantation crops.

The workshop commenced with a 'Stakeholder Forum' at which views were expressed by representatives of regional governments, agro-industries, researchers, and others on current and pressing issues related to tropical peatland utilization, particularly in the context of climate change and biodiversity conservation. These major issues were analysed and discussed in greater depth in four breakout sessions that prepared outline actions plans and contributed towards the symposium/workshop statement. Uniquely all parties recognized each other's needs with regard to peatland management and during the meeting they worked together to develop appropriate strategies and action plans to address current issues facing the tropical peatland resource.

The Yogyakarta International Symposium and Workshop:

WELCOMES the attendance of the representative of the Minister of Environment, Rektor of Gadjah Mada University, President of the International Peat Society, Governor of Yogyakarta, Ambassador of Finland and the First Secretary of the Netherlands Embassy in Jakarta; their support indicates a high level of awareness of tropical peatland problems and a desire for these to be resolved as matters of urgency.

NOTES the international interest in and concern for tropical peatlands and acknowledges that there are serious problems facing Governments in the ASEAN Region as a result of land use change and fire that are causing transboundary haze and a large increase in greenhouse gas emissions (GHG).

RECOGNIZES that all development on tropical peatland has associated environmental impacts while inappropriate or poorly managed development, especially over drainage, leads to peat subsidence and fire, which affect severely local and regional biodiversity, natural resource functions of the remaining peat swamp forest, and livelihoods and health of local people.

URGES the Indonesian and other ASEAN Governments to promote responsible management of peatlands, based on an ecohydrological approach that should prioritize the protection of high conservation value peat swamp forests, including semi-pristine and logged-over forests, and the rehabilitation of deforested, degraded peatland areas.

ENCOURAGES investment by all interested parties including international governments, donor agencies and the private sector in the conservation, rehabilitation and restoration of tropical peatland, and the improvement of existing peatland management practices by promoting wise use, including participatory management of this ecosystem in partnership with local communities;

EMPHASIZES the need for all stakeholders involved in peatland management to operate with accountability and transparency, develop new financial mechanisms and partnerships, undertake capacity building and apply appropriate technology in order to achieve success;

RECOMMENDS that land use planning of peatlands be optimized to promote their wise use and reduce greenhouse gas emissions.

Mitigation and Financing Initiatives to Increase/Maintain Carbon Stores in Tropical Peat

Carbon emissions from peatlands in Indonesia constitute a large problem causing haze, contributing to climate change processes, increasing loss of biodiversity and livelihood problems. This chain of events needs to be interrupted.

Carbon investments should take on board both poverty reduction and biodiversity in order to increase performance and sustainability of carbon investments. To generate capital and increase the returns on these investments, contributions of governments, industries (e.g. palm-oil and paper and pulp) and financial parties are crucial. To reduce risks and safeguard carbon investments in peatlands in Indonesia, two essential factors related to fires have to be addressed:

1. Poverty;
2. Reduction of excessive drainage (closely related to the uncertainty of precipitation changes).

Need for innovative financial mechanisms:

a. Globally:
   i. REDD; special peatland focused facility
   ii. Voluntary (private sector & public) investment schemes

b. Nationally: multi-donor trust fund

c. Regionally/provincially: provincial trust funds; private sector taxes (CSR)

d. Community level: micro-credit facilities and Bio-rights mechanism (www.bio-rights.org)

Need for new Institutional and management arrangements:

The financial mechanisms need to be backed up by new institutional finance management structures, policy and legislative frameworks and legal mechanisms to regulate, monitor and guide this new emerging market.

These should include

e. Consideration of the level, transparency and stakeholder involvement of governance of the funding, and facilities for pro-poor investment (e.g. integration of carbon conservation, poverty reduction and biodiversity conservation)

f. Recognition of customary rights

g. Monitoring and audit or certification mechanisms

h. Avoidance of leakage and perverse incentives through imbalanced land use planning: need for Master Plans for national and regional/local peat carbon emission reduction.

i. Standards and criteria for:
   i. Reduced emissions from avoided peat swamp forest deforestation and degradation,
   ii. Reduced emissions from optimization of water management in plantations (within a wise use approach)
   iii. Carbon sequestration through reforestation

j. Policies and legislation that can provide the necessary long-term guarantees for long-term carbon store conservation, including tenure aspects.

k. Hedge against risks (e.g. fire, natural disasters) through insurances and bank guarantees.

Need to show political will and stop expansion of the problem:

Evidence of political will is the key to attract investment. Indonesia's peatlands and current peatland issues provide for a potential avoided emissions of around 1.6 G ton (1.4 Gt from fires and 0.2 Gt from drainage (e.g. 30% of current annual drainage emissions)). A moratorium will be a strong signal and can be a first step in countering peatland degradation and to buy time to maximize the new opportunity of carbon finance. A moratorium needs to be part of a longer-term strategy of land use planning.

Development of Tropical Peatland for Agriculture and Forestry

Aims:

To promote responsible land-use development on peatlands that result in environmentally well-managed, highly productive and socio-economically beneficial agricultural/forestry development whilst at the same time protecting a representative sample of Indonesia's unique and biodiverse peatland heritage and minimising carbon loss.

Recommendations:

Land use planning

- Create a 'one stop centre' for peatland management, which simplifies institutional responsibility and accountability, integrates different land-use plans, requires better inter-agency cooperation and implements a high level of stakeholder (including local community) involvement.
- Develop an inventory and classification (definition) of existing peatlands, which can be used to identify appropriate land-use at the District level; future land use planning should be based on current peatland status including semi-pristine forest, irreversibly degraded/illegally logged peatland, agricultural peatlands and peat-based (including smallholder) plantations.
- Prioritise (using wise use criteria) and protect peatland for conservation according to hydrological status, size, habitat condition, biodiversity, ecological uniqueness, peat carbon storage capacity, substrate and different stakeholders' (including local communities') needs; these peatlands should remain under good forest cover and not be converted to plantations/ buffer zones.
- Use the eco-hydrological approach instead of the (3 m) peat thickness criterion for land-use planning, as greater biodiversity often occurs on shallower peat.
- Identify areas suitable for the promotion of alternative livelihoods (e.g. agri-business and integrated agro-forestry including animal husbandry) to provide food and cash and also biogas.

Involvement of stakeholders/local communities

- Establish proper coordination between government agencies and involve local communities and other stakeholders in the development of peatland for agriculture and forestry and the promotion of sustainable livelihoods. In particular:
    - stakeholder awareness of and involvement in fire prevention should be increased.
    - water and forest restoration should be community-based using wise use management

Fire

- Prevention of fire should be proactive and based upon peatland status, i.e. semi-pristine forest, irreversibly degraded /illegally logged peatland, agricultural peatlands and plantations.

Irreversibly degraded/illegally logged areas.

- Properly define degraded forest; prioritise future agricultural/plantation development on irreversibly degraded/deforested land.
- Promote more effective law enforcement targeted towards financiers and the market.

Semi pristine forests

- Maintain high water levels in semi-pristine and lightly logged forests by aiming for zero drainage and the restoration of their former hydrology by blocking existing drainage canals.

Existing major plantations

Advanced plantation management practices that aim to minimise carbon loss should be promoted and extended. Examples of existing wise use practice to build upon include:

- Development of advanced water and related peat resource management systems that seek to minimise drainage (e.g. the identification of species that will grow under waterlogged conditions).
- Development of integrated hydrological management plans for peatland which deal with the whole river basin and engages with different stakeholders that are active within the area.
- Active prevention of fire both within and adjacent to plantations.
- Inclusion of buffer zones and conservation areas on deepest peat/most important forest.
- Promotion of sustainable management as per government recommendations for plantations.
- Emphasis on stakeholder involvement in decision-making and income-earning opportunities for local people.

Rehabilitation and Restoration of Tropical Peatland

Needs:

- Government should revise the classification of 'production forest' with regard to peatlands, to take into account present levels of degradation (undamaged and primary, secondary and severly degraded land). Accurate maps are required of areas set-aside for different land uses. Management options should reflect these classifications and maps.
- Improve and up-date data base on peat area, depth, profiles and volumes.
- Prepare strategies for peatland:
  - *Conservation* – Locate and actively protect remaining peat swamp forest ecosystem.
  - *Rehabilitation* - Repair of degraded ecosystem,
  - *Restoration* - Back to original ecosystem,
  - *Reforestation* - Plantation activity, recovers some ecosystem function and some benefits,
- Ensure rehabilitation and restoration promote recovery of ecological and hydrological functions, including favourable carbon balance in line with wise-use principles, and that they have historical fidelity and improve local livelihoods.

Aims:

- Undamaged: rehabilitated forests can act as buffer zones, reducing need for activity in and access to pristine forest while providing alternative livelihoods.
- Primary degraded land should be enriched by planting native species; further degradation must be prevented, and local people should benefit.
- Secondary degraded land, (repeated logging/ degradation) requires positive rehabilitation through enrichment planting with native species, fire prevention, and hydrological recovery. These areas should be restored and used by local communities in a sustainable manner.
- Severely degraded land that has suffered from repeated disturbance is difficult to rehabilitate. Consider conversion to another land use (e.g. plantations) but applying wise-use principles.

Recommendations:

- Conserve the remaining peat swamp forest; reinstate hydrological processes, through construction of water flow retarders, especially on thick peat.
- Implement fire-fighting strategies to prevent and suppress wildfire, establish dedicated fire-fighting teams that are supported by a regular income.
- Commence scientifically based and community-informed rehabilitation programs that promote:
  - Planting of native, locally useful, marketable trees,
  - Recovery of ecosystem function, historical fidelity and
  - Improvement of livelihoods of local people.
- Government should:
  - Apply unified policies, enforce the law and apply sanctions;
  - Raise public awareness; educate small businesses and local communities;
  - Involve all stake holders (National and regional government, local communities, large and small private businesses) at each stage of land rehabilitation, through to long-term management;
  - Support community development programs, including local, regional and provincial involvement, through grass-roots programs, with education, long-term management and investment. Need for short-term monetary incentives and long-term beneficial outcomes for local communites, leading to ownership and tenure rights, and increased responsibilities.
- Further research is vital, especially by
  - establishing research sites across peatland areas to increase specific knowledge,
  - increasing rehabilitation knowledge, e.g. to identify native, but productive trees that can tolerate different environments, under different degradation levels, and will create incentives for local communities, e.g. jelutung, meranti, ramin, gemur.
  - by implementing alternative land clearing methods instead of fire.
- Generate funding guidelines for NGOs and other bodies

The Tropical Peatland Carbon Budget: Sinks, Stores and Losses

Background

Peatlands of the tropics represent archives of carbon. They have formed and vanished or buried over the last few million years – at present, few peatlands in SE Asia are older than 20,000 years; most of them are less than 10,000 years. These peatlands can therefore represent BOTH a carbon sink for, and source of, CO_2 and other gases from/to the atmosphere. Peatland use changes over the last few decades have necessitated drainage that has caused peat subsidence and a significant net carbon loss, which has been enhanced by accelerated decomposition and more frequent and severe fires.

The carbon cycle in tropical peatland

The carbon cycle on tropical peatlands differs under natural and land use changed conditions and is influenced by:

- Temperature, light, nutrients, water table;
- Biological: vegetation type, e.g. natural forest, arable cropping, plantations (biomass differs);
- Physical: wild fires, storms, etc;
- Management: cropping regime (no cropping, cyclic cropping, accidental cropping), water management (water table depth), soil management (tilling, burning, fertilisation, etc.)
- Change in C stock (peat structure, peat depth, peat area, soil gas fluxes, vegetation type.

What are Greenhouse Gas Emissions (GHG) from tropical peatland and how do they vary?

- The focus has been on CO_2 but CH_4 is important when water tables are high and N_2O is released under drained conditions when the water table is around 20 cm below the surface;
- There are diurnal and seasonal variations in GHG emissions;
- Addition of lime and fertilizers may change GHG emission patterns;

Factors affecting the tropical peatland carbon budget

- Logging (authorised and illegal); deforestation; drainage; subsequent land management and fire leading to:
- Cessation of carbon sink function, oxidation, increased decomposition, subsidence and increased GHG emissions;

Needs

It is urgent that:

- Different researchers collaborate to share data and standardize methods and analysis procedures;
- Gaps in knowledge are identified and more studies carried out of GHG emissions in ALL types of tropical peatland focussing on spatial and temporal variations over long periods (only three comprehensive studies have been carried out so far);
- Detailed study is made of the effect of biomass changes and crop composition on hydrology and soil structure that impact upon the peat carbon store and lead to loss of carbon to the atmosphere;
- Decomposition and subsidence that occur during development of tropical peatland are quantified better in order to solve some of the problems with data on the emission status of different peatland types;
- More and better information is obtained on the relationship between fire-releasing carbon, intensity and frequency, and the amount of biomass (fuel), water table and land use.
- Fire control and management should be prioritized in order to reduce GHG emissions from tropical peatland;
- Data presentation and synthesis are provided for policy decision makers.