Peatlands - guidance for climate change mitigation by conservation, rehabilitation and sustainable use

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MITIGATION OF CLIMATE CHANGE IN AGRICULTURE SERIES

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Peatlands - guidance for climate change mitigation by conservation, rehabilitation and sustainable use

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Executive Summary

Peatlands provide many important ecosystem services, including water regulation, biodiversity conservation and carbon sequestration and storage. Because of the enormous size of the peat carbon pool, its high sensitivity for disturbance, the large emissions from a small land area (which continue long after conversion), and the virtual irreversibility of peat carbon losses, any further degradation of the peatland resource should be prevented. Peatland conservation, restoration and better management are low-hanging fruits for climate change mitigation and climate-smart agriculture (CSA).

This report informs on management and finance options to achieve emissions reductions and enhance other vital ecosystem services from peatlands. A decision support tree guides through opportunities for both cultivated and uncultivated peatlands. Methodologies and data available for quantifying GHG emissions from peatlands and organic soils are summarized and practical solutions are given concerning measuring, reporting and verification (MRV) and accounting. Country-specific case studies illustrate the problems, solutions and opportunities of peatland management. This report is a good handbook for policy makers, technical audiences and others interested in peatlands.

10 elements of strategic action:

1. Identify occurrence and status (pristine, drained, abandoned, under productive use) of all peatland worldwide.
2. Improve assessment of greenhouse gas emissions from peatlands. Improve methodologies for measuring, reporting and verifying (MRV).
3. Conserve all reasonably intact peat swamps.
4. Prevent further degradation of already degraded peatlands including:
   - no further intensification of artificial drainage in already drained areas;
   - installation of hazard monitoring and mitigation schemes to avoid and restrain uncontrolled fires and soil erosion;
   - no further expansion of agricultural practices that require drainage (swap drained land use on peat, e.g. oil palm and pulpwood plantations, to mineral soils and apply paludiculture); and
   - no further uncontrolled selective nor illegal logging.
5. Restore degraded peatlands by rewetting, reforestation (in the tropics) and subsequent conservation and/or paludiculture. Restoration of peatlands reduces emissions, improves water regulation, benefits biodiversity and opens other income options.
6. Target financial resources to peatland conservation, restoration and better management.
7. Stimulate and apply existing and developing climate financing mechanisms on the compliance market (Kyoto Protocol, REDD+, NAMA's), the voluntary market (private sector investment in peatland rehabilitation) and from other sources.
8. Support local communities at the earliest stage and stimulate community development to overcome their opportunity costs and dependence on unsustainable peatland use.
9. Ensure that GHG criteria are integrated in credible certification and subsidy schemes for products that are derived from drained peatlands, including biofuels, palm oil, pulp wood, and other products from agriculture, horticulture and forestry. Each country that imports such products should review domestic policies for this.
10. Share experiences and expertise on peatland conservation, restoration and better management among countries rich in peatlands and organic soils – especially with those in need of capacity building.

This report provides guidance for these actions.

The main strategies are:

- Secure undrained peatlands to prevent emissions.
- Rewet drained peatlands to reduce emissions.
- Adapt management of peatlands that cannot be rewetted.

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Rome, May 2012, Hans Joosten, Marja-Liisa Tapio-Biström & Susanna Tol

Abbreviations

Acronym	Definition
AAUs	**Assigned Amount Units** Units issued to industrialized countries under the Kyoto Protocol in an amount equal to the caps they assumed.
Annex 1	**Annex I to the UNFCCC** Industrialized countries are listed in Annex I to the UNFCCC to differentiate obligations these countries have under the UNFCCC from those of developing countries. Most of the Annex I countries also agreed to binding caps under the Kyoto Protocol.
CAP	**Common Agricultural Policy** EU policy on subsidies for the agriculture sector.
CDM	**Clean Development Mechanism** Mechanism created under the Kyoto Protocol to finance climate mitigation projects in developing countries via creating CERs.
CERs	**Certified Emission Reductions** Offsets created by CDM projects that can be used by industrialized countries to meet their emission reduction commitments under the Kyoto Protocol.
CM	**Cropland Management** Type of activities that a country can choose to include in their LULUCF accounting under the Kyoto Protocol.
CMP	**Conference of the Parties serving as the Meeting of the Parties** The annual UN conference and decision making body for the Kyoto Protocol.
COP	**Conference of the Parties** The annual UN conference and decision making body for the UNFCCC.
CSA	**Climate Smart Agriculture**
CUPP	**Conservation of Undrained or Partially drained Peatland** VCS project category that would cover e.g. activities to protect a peatland from being drained.
DO	**Domestic Offsetting** Mechanism to create domestic offsets in the EU under the EU ETS.
ERUs	**Emission Reduction Units** Offset credits created by JI projects that can be used by industrialized countries to meet their emission reduction commitments under the Kyoto Protocol. ERUs are created by either converting an AAU or RMU into an ERU.
EU	**European Union**
EU ETS	**European Emissions Trading Scheme** Emissions trading scheme established in the EU.

FM	**Forest Management** Activities that involve the management of forests. This could include activities such as changing the logging rotation in a forest to increase the average carbon stock stored in the forest.
GCF	**Green Climate Fund** Climate fund and UNFCCC financial mechanism recently established under the UNFCCC to finance climate mitigation and adaptation.
GEF	**Global Environmental Facility** Facility to provide finance under UNFCCC and other environmental treaties (Convention on Biological Diversity, UN Convention to Combat Desertification, and Stockholm Convention on Persistent Organic Pollutants).
GHG	**Greenhouse gas** The six greenhouse gases listed in the Kyoto Protocol are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) Sulphur hexafluoride (SF_6).
GM	**Grazing land Management** Type of activities that a country can choose to include in their LULUCF accounting under the Kyoto Protocol.
JI	**Joint Implementation** Mechanism created under the Kyoto Protocol to finance climate mitigation projects in industrialized countries via the creation of ERUs.
KP	**Kyoto Protocol**
LULUCF	**Land use, land-use change and forestry** An umbrella term that covers a range of different types of activities affecting land and land use, such as FM, GM etc.
MRV	**Measuring, Reporting and Verification**
NAMAs	**Nationally appropriate mitigation actions** Actions undertaken in developing countries to mitigate climate change under the UNFCCC.
NAPs	**National Adaptation Plans** National plans developing countries are to develop to support adaptation to climate change.
Non-Annex 1	**Developing countries** See explanation of “Annex I”.
PRC	**Peatland Rewetting and Conservation** VCS project category that sets rules on accounting for emission reductions or removals for PRC projects.
RDP	**Rewetting of Drained Peatland** Projects that re-wet drained peat, e.g. by damming drainage canals.
REDD+	**Reducing Emissions from Deforestation and Forest Degradation**, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks. Topic being negotiated under the UNFCCC.

RMUs	**Removal Units** Units that are issued by Annex I countries if they generate net removals from their LULUCF accounting under the Kyoto Protocol.
UNFCCC	**United Nations Framework Convention on Climate Change**
VCS	**Verified Carbon Standard** Voluntary market standard used to quantify emission reductions or removals.
WDR	**Wetland Drainage and Rewetting** Type of activities that a country can choose to include in their LULUCF accounting under the Kyoto Protocol.

Zoige Plateau, the biggest peatland in the Tibetan Plateau with the altitude of 3500 m, where eco-tourism has been developed by local communities. Photo: Wu Ning

1. Introduction

Although the majority of peatlands are still in a natural state, many peatlands are drained and degraded. They have been used for centuries by humans for productive purposes such as agriculture, forestry, grazing and peat mining. Including emissions from peat fires, the CO_2 emissions from drained peatlands globally amount to some 2 Gigatonnes per year (Joosten, 2009a) and currently represent almost 25% of the CO_2 emissions of the entire land use, land use change and forestry sector (LULUCF) (Canadell, 2011). Unlike the emissions connected to forest clearance, which are largely instantaneous, the emissions from drained peatlands continue for decades and even centuries, i.e. as long as the peatland remains drained and the peat keeps oxidizing. By conservation, restoration and better management organic soils and peatlands can make a substantial contribution to reducing atmospheric greenhouse gas (GHG) concentrations while simultaneously providing other vital environmental services and contributing to food security and poverty reduction.

This report aims to provide countries rich in peatlands and organic soils with information on incentives to reduce emissions and enhance co-benefits, that exist and develop in the compliance market, the voluntary market and other mechanisms. The report informs on the methodological guidance and data available for quantifying GHG emissions from organic soils and provides practical solutions to attenuate possible concerns of countries for technical complications with respect to MRV and accounting problems. The information in this report was brought together by a team of expert authors from Wetlands International, the FAO Mitigation of Climate Change in Agriculture (MICCA) programme, Greifswald University, Climate Focus, ATLAS Environmental Law Advisory and Michael Succow Foundation who have contributed to different Chapters of the report. This report is a first version to which we would welcome any feedback or input.

According to Intergovernmental Panel on Climate Change (IPCC) fourth assessment report AR4, 14 % of the global GHG emissions are caused by agriculture. Further 17 % of emissions come from land use change leading to land use systems that contain less carbon than the natural ecosystem. It is therefore unrealistic to think that dangerous warming can be avoided without the land based sectors contributing to mitigation. Main land use changes are driven by agriculture changing forests to grazing lands and cultivated fields and grasslands to cultivated fields and by establishing biofuels plantations on natural forests. The human demand for energy, which is in many developing areas based on wood, further leads to forest degradation.

In order for the land use sector to contribute to the global effort to mitigate climate change, three actions need to be taken:

1. avoid new emissions from land use change and consequent land use,
2. improve management practices to reduce emissions from existing production systems and
3. sequester carbon through improved land use and management.

To achieve this it is necessary to identify the areas where reducing emissions from land use is most effective, so-called hotspots, while adequately considering other important societal goals including food security and maintenance of vital environmental services (see Box 1). Reaching food security for all is one of the main goals of the global community, national governments and individual households. Food security is a fundamental human right and a prerequisite to peaceful development. Since climate change will affect all ecosystems of the world including food production systems, building of resilience and adaptation to changing temperatures and rainfall patterns and quantities into land use and management decisions will be necessary. If global temperature increases by more than 2 degrees it will be very difficult to secure enough food for the global population, which is projected to increase to 9 billion people by 2050 before stabilizing.

We need to focus on emission hotspots such as peatlands and organic soils to reverse the trend of GHG emissions and to impede further dangerous climate change. Peatlands and organic soils cover only 3 % of the land area but contain 30 % of the soil carbon (Parish *et al.*, 2008). Of peatlands only some 15 % are taken into human use and drained for agriculture, livestock rearing and forestry including bio-energy (oil palm) plantations (Joosten, 2009a). These drained peatlands, on 0.3% of the world's land cover, emit, however, almost 6% of the global CO_2 emissions (Joosten, 2009a). Organic soils are prevalent in many agro-ecological zones and ecosystems and should be identified in order to establish suitable management programmes.

The obvious first choice is to conserve peatlands in their undrained state. Peatland conservation will be one of the most cost-effective ways to stop increasing emissions. The limited areas and huge carbon stocks involved make this a self-evident strategy which would benefit from a global focused programme to that end. Where natural peatlands have to be converted to productive use, land use options that are compatible with wet conditions, the so called paludicultures, should be developed and implemented.

Peatlands that are currently used for drained agriculture or forestry should be rewetted. Rewetting will often be easily feasible in areas where peatlands are already abandoned due to severe degradation or where productivity is low. There are already good examples where creative thinking, building on traditional knowledge and new science will give opportunities for developing sustainable livelihoods from rewetted peatland ecosystems. These will include paludicultures, of which the spectrum of possibilities still has to be explored, but also encompass diversification of income sources such as payments for ecosystem services and climate change mitigation funding combined with tourism development.

The emissions from drained peatlands are of global significance and constitute in a number of countries a major part of national GHG emissions. Therefore more sustainable and less harmful management practices have to be implemented in areas that have to be kept in productive use for agriculture, livestock and forestry. It is essential to identify management options to minimize emissions, including fire control. High water tables are essential to reduce emissions from cultivated and planted areas. Good practice guidelines should be developed for different agro-ecological zones and production systems. Reduced emissions through good practices could qualify as a practice based mitigation action.

Chapter 2 of this report provides an overview of the most effective strategies towards reducing emissions from organic soils according to the drainage condition they are in, which is strongly associated with ecosystem services provided and environmental problems instigated. This Chapter discusses management practices to avoid or mitigate these negative effects. For peatlands under productive use we provide guidance how to increase the sustainability of land use and present the opportunities, benefits and trade-offs of changing management. Chapter 3 informs on the finance options to reduce emissions and enhance co-benefits through peatland conservation, restoration and sustainable use, as they exist and develop in the compliance market, the voluntary market and other mechanisms. Chapter 4 discusses available methodological guidance and data available for quantifying greenhouse gas emissions from organic soils and provides available and practical solutions for possible concerns with regard to accounting and MRV. The final Chapter 5 brings exemplary application for key countries to the attention of policy makers, technical audiences and beyond.

Box 1: Ecosystem services of peatlands: the Ruoergai Plateau (China)

The extensive Ruoergai (Zoige) peatlands on the Tibetan Plateau are major interfaces between the Tibetan uplands and the big lowland rivers. From early times, the peatlands acted like sponges: they absorbed and retained water during periods of large water supply and slowly released it in times of water deficit. In this way they slowed down peak discharge, prevented erosion, reduced downstream flooding, and guaranteed a steady water supply to the Huanghe (Yellow) River. Millions of people are dependant of the Huanghe's water.

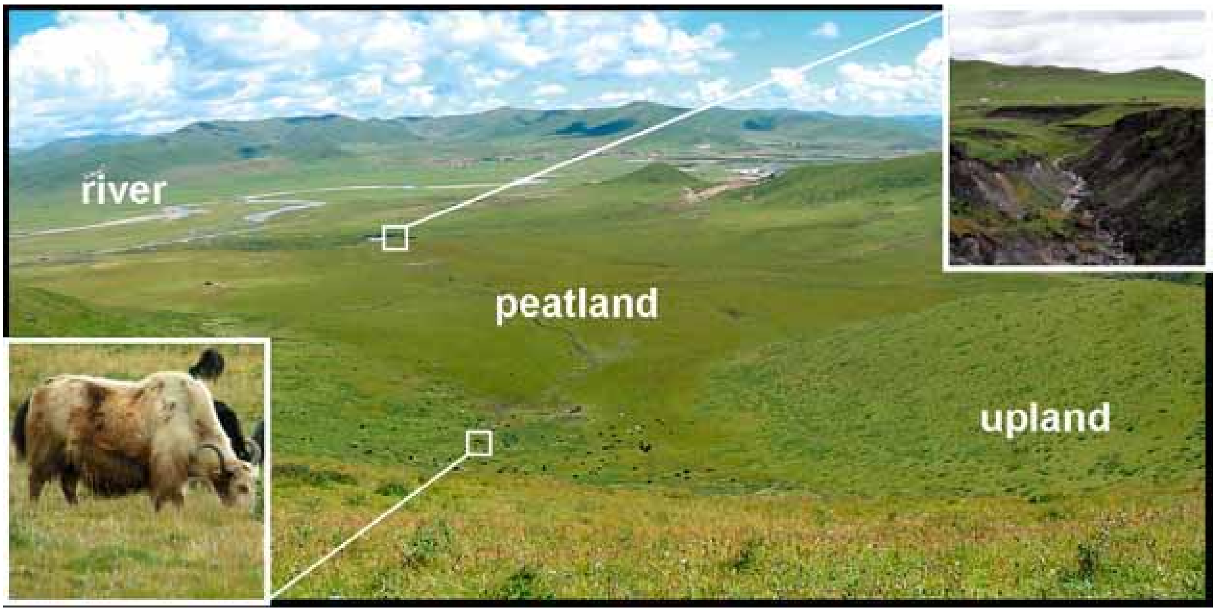
The introduction of cattle grazing 5000 years ago changed the character of the peatlands which became more susceptible to erosion (Joosten *et al.*, 2008). Simultaneously a complex system of land management developed as part of a unique cultural heritage that included the sharing of grazing lands and their rotational use. Long before recent intensification, grazing had thus made the peatlands vulnerable to degradation (Schumann *et al.*, 2008).

With the construction of roads in the 1970s and the rising demand for food, fuel and rangeland, degradation increased dramatically. Overgrazing and the resulting decrease in pasture quality fuelled the demand for new rangeland. This led to increased pressure on undrained peatlands (Wiener *et al.*, 2003, Wang *et al.*, 2006; Gao *et al.*, 2009) of which almost 50 % were drained (Yang, 2000). In order to increase milk and meat production, traditional husbandry was replaced by a more market-oriented economy. Collective livestock and pastures were divided and allocated to individual households (Yan and Wu 2005). As a result livestock numbers increased dramatically (Li *et al.*, 1986; Long and Ma 1997).

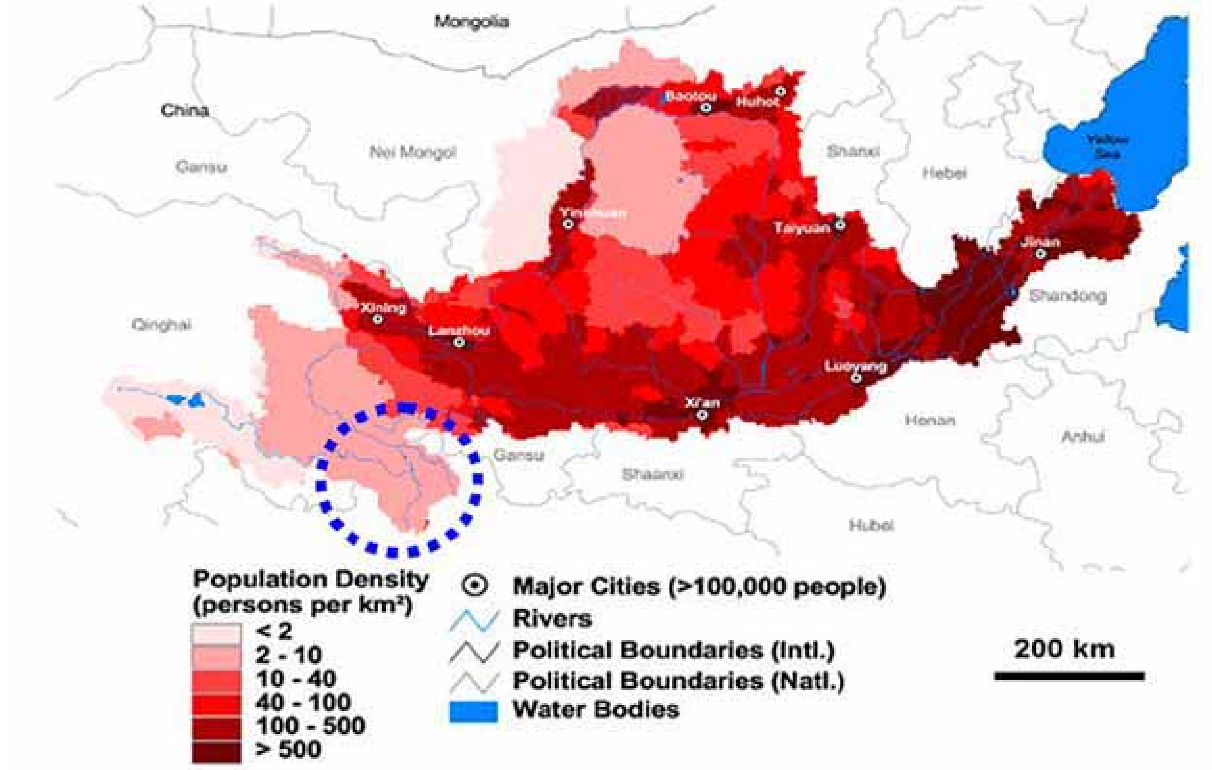
During the last fourty years the area of degraded peatlands has almost doubled and less than 20 % of the peatland remains of good quality in the Ruoergai Plateau (Schumann *et al.*, 2008). The degradation causes severe ecologic and socio-economic problems. In order to recover peatland functions and services, Wetlands International China carried out various pilot projects with financial support of UNDP-GEF (1999-2007), the Global Peat Initiative (2002-2003), UNEP-GEF (2003-2006) and the EU-China Biodiversity Programme (2007-2010) (Zhang *et al.*, 2012). Peatland restoration by ditch blocking started in 2004 in Ruoergai and Hongyang counties (Sichuan Province) and extended to Maqu and Luqu, (Gansu Province). In 2007 and 2010 the Provincial People's Congresses of Gansu and Sichuan approved Wetland Conservation Regulations that prohibit drainage, peat mining and reclamation of peatlands. The Sichuan Regulation explicitly encourages local people and organizations to involve in peatland restoration and allocates 0.3 % of its yearly budget to peatland restoration. Local governments developed programmes to control erosion and to reduce stock numbers to ensure a more sustainable use of resources (Schumann *et al.*, 2012).

The Ruoergai example shows how wise management can serve multiple goals. Currently the peatlands provide irreplaceable grazing ground for thousands of yaks, horses and sheep that are the livelihood of Tibetan herder families and provide China with milk and meat. By keeping groundwater levels high, the peatlands maintain the productivity of upland rangelands. By reducing the speed of water flow, the peatlands retain sediments and supply well-filtered water of good quality. The peatlands furthermore contain, with an estimated carbon content of 750 Mt (Björk, 1993), a major part of the Chinese peat carbon resources, and are important for biodiversity conservation with numerous endangered and endemic species (Tsuyuzaki *et al.*, 1990; Ekstam, 1993; Schaller, 1998).

The Ruoergai peatland pastures on the Tibetan Plateau: a major milk and meat producing area in China.
Photo: Martin Schumann



The Ruoergai peatland pastures on the Tibetan Plateau are major interfaces between the Tibetan uplands and the big lowland rivers.
Photo: Martin Schumann



The Ruoergai peatlands on the Tibetan Plateau are crucial for regulating water supply to the lowland Yellow River basin. (Water resource eAtlas, AS09 Huang He (Yellow River), http://earthtrends.wri.org/pdf_library/maps/watersheds/as10.pdf)

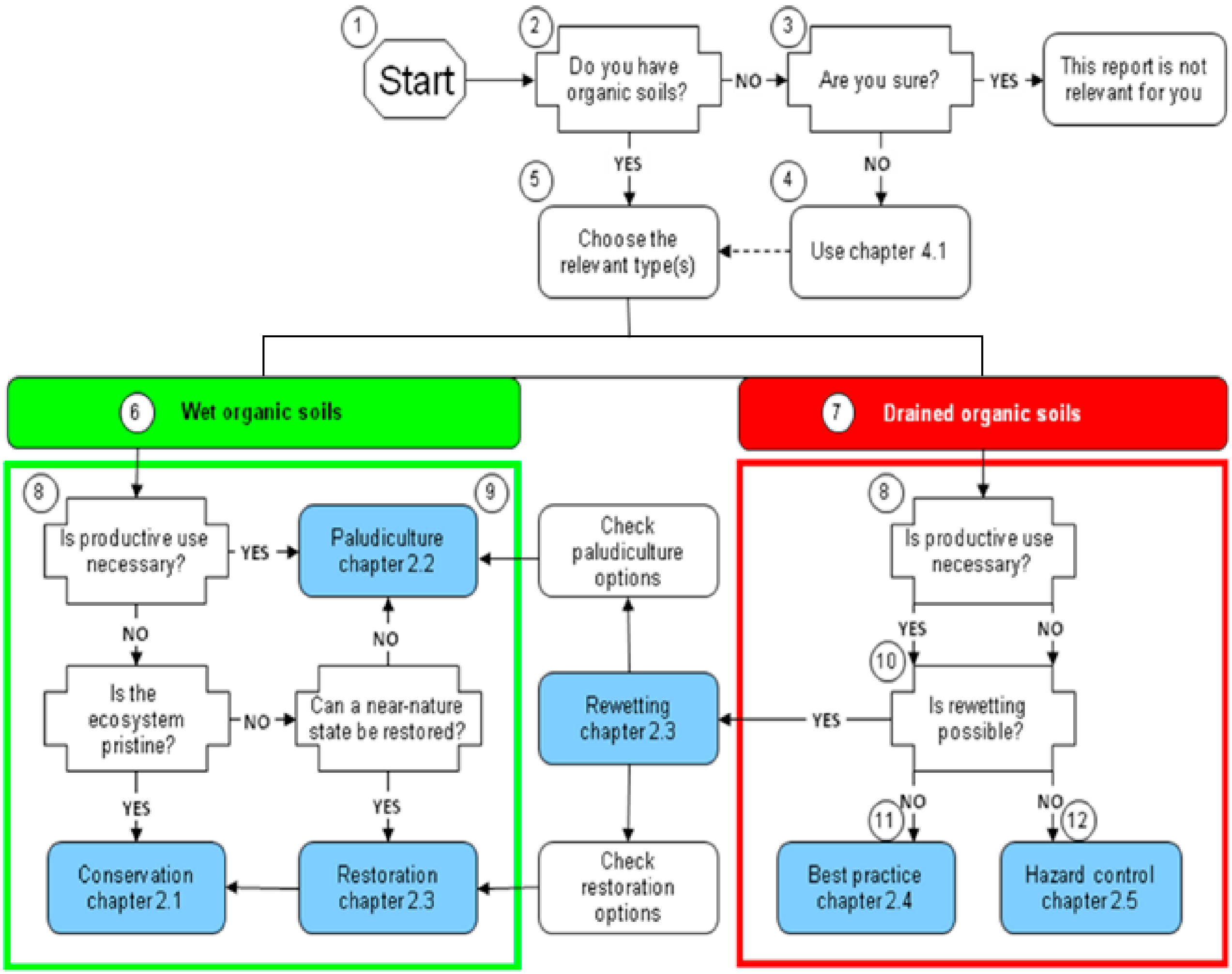


Figure 1. Decision support tree for management of peatlands/organic soils

2. Implementation

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Peatland drainage - mainly for agriculture, grazing and forestry - is associated with many environmental problems (Chapter 2, Box 2: subsidence) that eventually may destroy the peatland subsistence base. This Chapter discusses management practices that can avoid or mitigate these negative effects. The key management options (cf. decision support tree, (Fig. 1 see page 8)”), both for cultivated and uncultivated peatlands, can be summarized as:

1. Keep wet peatlands wet!
2. Rewet drained peatlands!
3. Adapt management where peatland cannot be rewetted.

1) This decision tree guides through the document.
2) Organic soils (≈ peat soils) are soils with a substantial layer of organic matter at or near the surface
3) Almost all countries of the world have organic soils. If you are not completely sure, choose ‘NO’.
4) Chapter 4.1 suggests data sources and data suppliers with respect to organic soils in your country.
5) The drainage condition of organic soils is strongly associated with the ecosystem services provided and environmental problems instigated (see below).
6) Wet organic soils are inundated or saturated by water for all or part of the year to the extent that the prevailing soil biota and rooted plants are adapted to anaerobic conditions. Wet organic soils retain carbon and emit methane. Worldwide, most wet organic soils are not in productive use (see 8).
7) Drained organic soils are organic soils that are not ‘wet’ (see 6). They are subject to inherent degradation (see Fig. 2 and Box 2), loose carbon and emit carbon dioxide (and often nitrous oxide). Most organic soils used for agriculture, grazing or forestry are drained.
8) On land under ‘productive use’, management (for retrieving food, feed, fiber or fuel) controls the composition and volume of the standing biomass.
9) Organic soils can be used productively without drainage in so called ‘paludicultures’. Rewetting of drained degraded soils may reinstall productivity and decrease environmental problems.
10) Continuation of productive use on drained organic soils inevitably leads to loss of productivity on the long run. Drainage requiring land use should - whenever possible - be swapped to mineral soils.
11) If land swap is not feasible, management must be adapted to mitigate environmental problems and to extent land productivity as long as possible.
12) Drained and abandoned organic soils without proper management are prone to uncontrolled fire events and soil erosion. It is recommendable to install a hazard monitoring and mitigation scheme.

Figure 2. The vicious clogs of drained peatland utilization

Box 2: Subsidence

One of the key issues related to peatland degradation is subsidence, which results from peat oxidation, shrinkage and compaction (Andriesse, 1988; Dradjad, 2003; Schothorst, 1977; Couwenberg *et al.*, 2010; Hooijer *et al.*, 2012). Initial subsidence in newly drained areas is mainly caused by compaction and can be more than 50 cm yr^{-1}, depending on drainage level and type and depth of the peat. After a few years, oxidation becomes the main factor causing up to 90% of the subsidence (Stephens *et al.*, 1984; Hooijer *et al.*, 2012).

Most coastal peatlands have originated thousands of years ago when the sea water level was much lower than at present and have grown up with the rising sea water level. As a result their basal peat layers lay mostly (sometimes deep) below the current sea level. In such peatlands subsidence will render gravity drainage impossible when the land surface has subsided to near or below sea or river level. The associated loss of habitable and productive land can only be avoided by installing pump-operated drainage, which, however, requires significant investment in dikes and pumping capacity. In the Netherlands (the "Low Lands") continuous (pump-operated) draining has resulted in almost half of the country lying currently several meters below sea level. Similar problems are known from various parts of the world.

In South-east Asia the deep drainage required for common land use (i.e. oil palm, Acacia pulp wood, Miettinen *et al.*, 2012b) with consequent high oxidation rates (Hooijer *et al.* 2012, Jauhiainen *et al.*, 2012) is expected to result within several decades in serious floods due to subsidence. In tropical climates with over 2000 mm of annual precipitation pump operated drainage will not be feasible for the millions of hectares of coastal peatlands under cultivation in Sumatra and Borneo (currently 3.1 Mha, projected 6 to 9 Mha by 2020; Miettinen *et al.*, 2012b). In Sarawak, where most coastal peat swamps have been allocated for oil palm plantation development, subsidence may over time lead to the loss of over 10% of the entire land area. In addition, reduced steady freshwater supply from deforested and drained inland peat swamps makes coastal mineral soil areas more vulnerable for drought and salt water intrusion and reduces the feasibility of agriculture in these areas which often have acid sulphate soils (Silvius *et al.*, 2000). Sea level rise will amplify the risk of flooding (Cruz *et al.*, 2007).

While drained peatland use in the short term may reap significant economic profits, its inherent unsustainability may in the longer term have severe socio-economic consequences, not only in relation to their disproportionately large contribution to climate change. Policy makers stand for the choice between the continuation of unsustainable peat swamp development with short-term economic benefits, or the conservation, restoration and non-drainage land-use options that will provide long-term sustainable benefits for the local communities, the country and the world at large.

Preparing seedlings for reforestation of drained and deforested tropical peat swamp (Central Kalimantan, Indonesia). Photo: Hans Joosten

2.1. Keep wet peatlands wet: conservation

The natural condition of peatlands is that their soils are (almost) permanently wet. Only this wet condition allows the accumulation and maintenance of the enormous stocks of soil organic carbon that we call peat.

The most obvious option for preventing environmental problems associated with peatland drainage is to refrain completely from using peatlands for cultivation ("conservation"). Conservation does not mean that such peatlands have no value or purpose. Indeed undrained peatlands provide a multitude of valuable ecosystem services both to individual consumers and to society (Joosten and Clarke, 2002). Conservation of undrained peatlands is purposeful, as intact ecosystems are kept intact without the necessity of expensive investments for (often unsuccessful) repair. Conservation is also often a very cost-effective management option.

Effective conservation is, however, hampered by many parties having insufficient knowledge of the value of peatland environmental services (carbon storage being an important one) and of peatland occurrence and distribution in their country. Mapping of peatland is especially urgent in the tropics and subtropics to avoid uncontrolled and possibly highly negative developments. Successful peatland conservation thus requires that we rapidly chart the peatland white spots on the map to prevent them from becoming new emission hotspots. A reasonable overview of major peatlands occurrences in the worldwide tropics can rapidly (within one year) and cheaply (less than 1 million dollar) be reached with modern remote sensing techniques, compilation of dispersed literature and limited ground truthing (see Chapter 5 Congo Basin and Amazon Basin).

The limited success of restoration activities - especially in the tropics - demonstrates that much damage done to peatlands is irreversible. Thus conservation of the remaining peatlands in their natural state is the best mitigation option leading to avoidance of globally significant emissions through oxidation and peat fires.

Funding of conservation through climate financing mechanisms only is, however, problematic. The short term gains from conversion of peatlands to - for example - oil palm cultivation cannot be matched by carbon credits. The long term costs to society of land degradation and loss and of high emissions are, however, solid rational for conserving remaining undrained peatlands. Hence countries will have to cover the short term opportunity costs themselves by banning such plantations for ensuring the long-term benefit of the ecosystem services. Possibly other financing mechanisms from development or sectoral and private sector funding can provide an attractive win-win of climate change mitigation linked to securing livelihoods and new - sustainable - income options for local people.

2.2. Keep wet peatlands wet: paludiculture

Drainage based peatland utilization causes peat oxidation, soil subsidence, nutrient losses to ground- and surface waters, greenhouse gas emissions (Wichtmann and Wichmann, 2011) as well as peatland fires and haze (Couwenberg *et al.*, 2010). Several of these processes destroy in the long run the subsistence base of productive use.

Keeping or making peatlands wet prevents and reduces these environmental impacts, but implies that the area is lost for standard agricultural use. Peatlands have been and are converted to agriculture or forestry. Most of this land use is characterized by intensive drainage, since most conventional cultivated plants require low water tables and heavy machinery was not adapted to water logged conditions. Meanwhile, however, more and more land management and crop processing technologies have been developed that remove these bottlenecks.

Paludicultures (Latin 'palus' = swamp) are land management techniques that use biomass from wet and rewetted peatlands under conditions that maintain the peat body, facilitate peat accumulation and provide the ecosystem services associated with natural peatlands. Paludicultures allow to stop peat oxidation and simultaneously to provide sustainable harvests from peatlands. Paludicultures use only that part of net primary production that is dispensable for peat formation. In the temperate, subtropical, and tropical zones, i.e. those zones of the world where plant productivity is high, peat is generally formed by belowground roots and rhizomes and peatlands by nature hold vegetation of which aboveground parts can be (selectively!) harvested without substantially harming peat formation (Wichtmann and Joosten, 2007).

The "paludibully" wetland harvester for mowing, choppering and gathering reed from wet peatlands. Photo: Hans Joosten

Paludicultures comprise any biomass use from wet and rewetted peatlands, from harvesting spontaneous vegetation on natural sites to artificially established crops on rewetted sites (Joosten *et al.*, 2012). Paludicultures, thus, may have a double positive climate change mitigation effect: they avoid greenhouse gas emissions (by preventing peatlands being drained or by rewetting drained peatlands) and the biomass produced may replace fossil raw materials and fossil fuels (Wichtmann and Joosten, 2007). Besides for food, feed, fiber, and direct combustion, the biomass from paludiculture can be used as a raw material for industrial biochemistry, for producing high quality liquid or gaseous biofuels and for synthesizing pharmaceuticals and cosmetics (Joosten *et al.*, 2012).

An obvious paludiculture practice is collection for direct consumption. In the boreal zone of Eurasia a wide variety of wild edible berries (*Vaccinium*, *Empetrum*, *Rubus*, *Ribes*) and mushrooms are gathered for food and vitamins (Joosten and Clarke, 2002). In Russia and Belarus these provision services have been major justifications for protecting and restoring mires. In other parts of the world a variety of plants for human nutrition or medical use are collected from wet peatlands, such as wild (so-called 'floating') rice (*Zizania aquatica*) (North America), bog bean (*Menyanthes trifoliata*), calamus (*Acorus calamus*), and buffalo gras (*Hierochloe odorata*) (Europe) or sago palm (*Metroxylon sagu*) (Indonesia, Malaysia) (Joosten and Clarke, 2002; Joosten *et al.*, 2012). Other traditional low intensity or soft uses include hunting and fishing (Wichtmann, 2011). Especially in tropical peat swamp forests fisheries is a major economic activity and aquaculture of indigenous fish species can be an attractive land-use option and economic incentive for local communities in areas where many drainage canals are to be blocked for hydrological restoration.

In recent years various options for site adapted land use on wet and rewetted peatlands have been developed and tested (Wichtmann and Tanneberger, 2011; Table 1). Some of them revitalize traditional forms of land use through new utilization schemes, e.g. reed cutting for new developed construction materials like insulation panels. Others, such as biofuels, provide innovative products for growing market demands.

Table 1. Examples of paludicultures tested in Central Europe (after Abel *et al.*, 2011)

Peatland type	Plant species	Utilisation
Bog (oligotrophic)	Sphagnum sp.	growing media
Fen (oligo- eutrophic)	Alnus glutinosa	furniture, timber, fuel
Fen (polytrophic)	Phragmites australis	animal fodder (in and ex situ), roofing material, form bodies, paper, chemicals, fuel (direct combustion, pellets, fermentation)
Fen (polytrophic)	Typha latifolia	insulation and construction materials, fuel (direct combustion, fermentation)
Fen (eutrophic - polytrophic, base rich)	Phalaris arundinacea	fodder (in and ex situ), fuel (direct combustion, pellets, fermentation)
Fen (oligotrophic - polytrophic, base rich)	Carex sp.	stable litter, fuel (direct combustion, pellets, fermentation)
Fen (polytrophic)	Glyceria maxima	fodder (in and ex situ), energy (direct combustion, pellets, fermentation)

Rewetting as a precondition for paludicultures converts drained peatlands into peat forming ecosystems, even if peat formation is a very slow process, and thus into sinks for carbon and nutrients and filters of water (Trepel, 2010a, b; Grosshans *et al.*, 2011). Rewetting reduces GHG emissions from peat oxidation and peat fires substantially (Couwenberg *et al.*, 2011; Parish *et al.*, 2008).

When used for cost-effective biomass production, the wet land use of peatlands for cultivation causes lower GHG mitigation costs than many other bio-energy options (Schäfer, 2012). For rewetted sites, the sale of 'carbon credits' from emission reductions by rewetting (O`Sullivan and Emmer, 2011) can provide income in addition to the earnings from the biomass production for energy itself. Paludicultures may furthermore provide sustainable income to rural livelihoods from primary production on sites that were abandoned or where a subsidy-oriented, environmentally damaging land use took place, such as in Europe. In the temperate zone, autumn and winter harvest leads to more consistent employment throughout the year, whereas biomass processing may create net added value and generate additional jobs. Paludicultures can contribute to energy autonomy and help regional economies, also by improving perspectives for (eco)tourism (Joosten *et al.*, 2012).

2.3 Rewetting and restoration of drained peatlands

Conventional peatland utilization requires a lowering of the water table. As peat largely consists of water, peatland drainage leads to subsidence and compaction of the peat. Consequently, the hydraulic properties of the peat change, which may decrease the peatland's capacities for water storage and regulation. Peatland drainage leads to oxidation of the peat layers that are no longer saturated with water. Drained peatland consequently loses - depending on the climate - some millimeters up to several centimeters of peat per year. These losses are accelerated by addition of lime, fertilizers and clastic material, by water and wind erosion and by (subsurface!) peat fires. The resulting lowering of the peatland surface necessitates a continuous deepening of the drainage ditches, which again enhances peat oxidation, surface lowering, ditch deepening,…: "the vicious circle of peatland utilization" (Figure 2).

Peat oxidation leads to increased emissions of greenhouse gasses (CO_2 and N_2O) and nitrate (which may over-fertilize adjacent surface waters). Particularly in drier climates, water level fluctuations cause the formation of peat fissures, which impede upward (capillary) water flow and lead to frequent and deeper drying out of the soil. Through activity of soil organisms, drained peat soils become loosened and fine-grained and may eventually become totally water repellent. All these processes negatively affect:

Box 3: Paludiculture in Indonesia

Thus far no true paludicultures have been established in Southeast-Asia. However, during the past ten years numerous reforestation trials on degraded peatland have been developed. These trials also use trees that provide valuable non-timber forest products (NTFP). A popular species often planted in reforestation attempts is Jelutung (*Dyera* sp.), a latex producing tree. The largest Jelutung plantation was established by PT. Dyera Hutan Lestari in Sumatra. This company planted over 2000 ha and started tapping of *Dyera latex* (Muub 1996). Sadly the plantation burnt down due to escalating fires from adjacent areas (Giesen & van der Meer 2009). Wetlands International-Indonesia Programme also planted Jelutung trees in peatland rehabilitation projects in Sumatra and Kalimantan. Other typically planted species are valuable hardwood timbers such as Belangiran (*Shorea balangeran*) or Ramin (*Gonystylus bancanus*).

These and other peat swamp timbers have the potential to be commercially planted on rewetted peatland. Moreover, pioneer species that dominate after disturbance such as *Alstonia pneumatophora*, *Combretocarpus rotundatus* and *Macaranga pruinosa* are possible surrogates to exotic *Acacia* species in the production of pulp. A famous peat swamp tree that is harvested in the wild, in fact often locally overexploited, is Gemor (*Alseodaphne coriacea*). The bark of this medicinal plant is used as a mosquito repellent and sold on local markets (Suyanto *et al.* 2009). This species is only one example of numerous medicinal plants that could be widely planted. Food production is extremely important in rural areas of Indonesia. In the inhabited peatlands of Sumatra and Kalimantan trials with food plants that don't require drainage have to be developed, especially with permanent crops that reduce fire risks associated with annual crops and related land clearing practices. Traditional mixed tree gardens with fruit trees and wet agroforestry schemes are promising ways of small-holder paludicultures with focus on food and NTFP production. The hutan-desa forest concession type allows villages to sustainably harvest timber, implement enrichment planting (including valuable rattans) and perform agroforestry on areas up to 10 000 ha. Similar problems are known from various parts of the world.

- flood control, leading to flooding downstream;
- water storage capacity, decreasing the regular supply of drinking and irrigation water;
- agricultural production capacity;
- carbon storage and climate change mitigation capacity;
- biodiversity; and
- the use of peatlands for recreation, hunting and gathering.

Rewetting of peatlands has the highest priority for addressing peatland degradation and biodiversity loss and for mitigating CO_2 emissions from peat oxidation and peatland fires (Parish *et al.*, 2008).

The **rewetting** of drained peatland involves the partial or entire reversal of former anthropogenic drainage by elevating the average annual water table. The major aim is to achieve permanent water saturation of the entire peat body by raising the water table to close to or above the peat surface and by reducing the amplitude of water level fluctuations. If feasible, deep and permanent flooding should be avoided, because deep water is difficult to be colonized by emergent vegetation. Temporary pools and flooding can, on the other hand, also stabilize water levels (large storage capacity), such as in tropical peat swamps (Dommain *et al.*, 2010). Rewetting is achieved by reducing water losses from the site (by decreasing surficial drainage, surface runoff, sub-surface seepage, groundwater extraction, and evapotranspiration) and by - where relevant - increasing water supply from the catchment.

There is no universal strategy to rewet drained peatlands as conditions differ widely. The *most important technical criteria* for rewetting are:

- **Water availability**: The assessment of water availability may require addressing climate, peat hydraulic conditions, drainage infrastructure, water regime, topography and the hydrogeology and hydrology of the peatland's hydrological catchment.
- **Land use**: both inside the peatland and in its hydrological catchment area. If current land use requires drainage, partial rewetting can be considered or land use can be changed to paludiculture (see Chapter 2.2). If ensuring water supply for rewetting requires a reorganization of land use within the hydrological catchment, it is necessary to check feasibility and costs and to involve stakeholders.
- **Relief**: The water level that can be established is highly dependent on the peatland's relief and topography. Also without active peat removal the relief of a peatland may have changed substantially by subsidence, peat oxidation and fire. To achieve the best effect, the average annual water level must be raised to around the surface over the largest possible area of the peatland.
- **Tree growth**: Trees may have a negative impact on hydrology as they may enhance evapotranspiration. Trees may, however, also have a positive effect on the micro-climate (by reducing wind velocity and increasing shade), whereas in tropical peat swamps the presence of (large) trees is even a prerequisite for optimal rewetting (Dommain *et al.*, 2010).

Water availability and relief are often the ultimate factors determining rewettability and may have changed to the extent that optimal rewetting has become impossible. Partial rewetting will then still reduce the environmental risks (see Chapter 2.4).

The **restoration** of a peatland aims at revitalizing the peat accumulation process. Restoration must always include rewetting. In a peatland strong interrelationships exist between plants, water, and peat: when one of these components is affected, eventually also the other components will change. The components are, however, not equally vulnerable, nor do they react simultaneously. Generally organisms are more easily affected than hydrology and hydrology again much easier than the hydraulic and morphologic properties of the peat body. As the latter components exercise the strongest long-term control on the development of the peatland, activities must focus on restoring these components first. Again: there is no universal strategy to restore degraded peatlands, as conditions differ widely.

The *most important technical components***,** that (additional to the criteria for rewetting above) determine the restoration potential, are:

- **Peat hydraulic conditions**: If the upper peat layer is strongly decomposed, strongly compacted or degraded, the potential of restoring mire types that require non- or little humified peats to regulate their hydrology is severely limited. In such peatlands restoration can initially only focus on preserving residual floral and faunal communities and on re-developing pioneer mire types (Schumann and Joosten, 2008).
- **Relief**: In degraded peatlands, drainage, peat extraction or fire have often changed the peatland relief substantially. This will have affected the water balance of the peatland, in particular the proportion of water that is transported through and over the peat body. The results cannot easily be predicted because a change in relief triggers a whole chain-reaction of processes with opposing effects (Abel *et al.*, 2011).
- **Vegetation**: Vegetation is easily affected by cutting, mowing, draining and sod removal. When vegetation change is the only impact (and other peatland components are not affected), restoration only requires the removal of the disturbing factor. Then the peatland will regenerate spontaneously, provided that sufficient diaspores of the key plant species are available (if not, introduction of diaspores has to be considered). The same accounts in case the water balance of the peatland has only recently been affected and no irreversible changes in peat hydraulics or peatland relief have yet taken place. Also then the peatland can easily be restored by removing the disturbing factor.

For more information on rewetting and restoration, see the Global Peatland Restoration Manual (Schumann and Joosten, 2008).

Restoration often requires complete hydrological systems (full peat domes, sub-domes, other integral hydrological units) to be available for re-wetting. Land use planning should address land use options from an ecosystem perspective, aiming at preserving the vital environmental services at the landscape level. In addition to rewetting, in the tropics reforestation with indigenous tree species, fire prevention and establishment of fire control capacity are critical for successful and sustainable rewetting and rehabilitation.

The *main principles* to peatland rewetting and restoration are:

- Rewet as quickly as possible! The effectiveness of peatland restoration strongly depends on the degree of degradation. The longer a peat body has been dissected by drainage channels, the more the newly originated mesorelief may frustrate full-scale rewetting and emission reduction.
- Reforest (in the tropics)! The hydrology of natural (zero-emission) peat swamp forest is maintained by the forest above-ground root system and related surface elevation differences (Dommain *et al.* 2010). Therefore reforestation must be part of any restoration effort.
- Ensure support of local communities at the earliest stage! Drainage infrastructure often provides access to the peatland to local people. Restoration may restrict this access again (by blocking canals) and locals may therefore oppose restoration. It is thus of crucial importance to consult local communities and involve them actively in the planning, design and implementation of restoration work.
- Stimulate community development! To enable communities to overcome dependence on unsustainable peatland use, peatland rehabilitation projects, which may result in opportunity costs for local communities, should include community development as an integral component to offset such opportunity costs.

Box 4: Restoration and conservation

Peatland restoration is a good way to reduce the CO_2 emissions from drained peatlands, but it is always a second best approach to conservation. Restoration of a peatland site can only reduce the emissions to zero, if the entire area can be adequately rewetted. The experiences in Indonesia have shown that - certainly in the tropics - complete rewetting is often very difficult or even impossible to achieve, because drainage has induced irreversible changes in peatland relief. Stronger soil subsidence immediately adjacent to drainage channels results in the formation of 'mini-domes' in between such strongly subsided areas which prohibits full rewetting over large areas. The areas that are not sufficiently rewetted will continue to emit GHGs until a new hydrological equilibrium is reached. Achieving full rewetting will often take several decades. This implies that restoration of degraded peatland cannot compensate for peat swamp conversion on a hectare-by-hectare basis. To compensate for emissions of newly drained peatlands much larger areas of degraded peatland landscapes will have to be subject to long-term rewetting and reforestation.

2.4 Adapted management of drained peatlands in productive use

Whereas paludicultures represent the only sustainable mode of agricultural production on peatlands, technical or socio-economic constraints may prevent drained peatlands from being optimally rewetted. In such cases the negative environmental and socio-economic impacts of utilization should be restricted by:

- Minimizing drainage as far as possible to reduce peat oxidation and land degradation.
- Choosing crops that are adapted to high soil moisture. Crops that require deep drainage are not suitable for agriculture on peatlands.
- Avoiding plowing, as tillage enhances peat oxidation by increasing soil surface roughness.
- Cultivating permanent crops that with their shade reduce surface temperatures and consequent increased peat oxidation (Jauhiainen *et al.*, 2012) and avoid land clearing by fire as is often practiced when cultivating annual crops.

- Limiting fertilization as fertilization generally increases peat oxidation (Clymo 1983) and nitrogen fertilization on drained peat soils may result in huge emissions of nitrous oxide, especially after rain (Couwenberg *et al.*, 2010).

2.5 Hazard control on abandoned drained peatlands

Millions of hectares of drained peatlands in the world have become so low productive and degraded that they have been abandoned. In these peatlands, the old drainage systems continue working long after abandonment. In the absence of management, abandoned drained peatland sites are susceptible to fires. Abandoned over-mature forests on drained boreal and temperate peatland or partly logged and previously burned forests in the tropics may have accumulated much inflammable dead wood litter and the dry peat beneath is easily ignited during fire hazards in dry seasons.
Peatland fires occur mainly on peatlands with unclear ownership and responsibility. Peat fires are mostly induced by human activities in or in the surrounding of the peatland. A peatland is fire prone if it is:

- drained;
- abandoned (without regular surveillance); and
- regularly visited by people (e.g. for hunting, gathering, recreation).

Peatland fires can only be prevented when peatlands have a clear economic value or when they are effectively rewetted. Rewetting not only precludes peat fires but also strongly reduces microbial peat oxidation and consequent CO_2 and N_2O emissions.

Fire control exercises in the Mega Rice Project area (Central Kalimantan, Indonesia).
Photo: Hans Joosten

As long as rewetting and/or regular economic use are not implemented, fire control must attempt to prevent hazards. Effective fire control includes:

- monitoring by satellite or airborne observation, watchtowers and ground patrols;
- establishment of hydrants or ponds to guarantee water availability;
- stand-by of sufficient fire brigades;
- training in fire prevention/suppression and disaster management; and
- adequate communication structures and coordination.

The high costs of maintaining an operative fire control infrastructure, combined with the abundance of lightly inflammable fuel make fire control in drained and abandoned peatlands an unappealing alternative. It furthermore does not solve the problem of continuing greenhouse gas emissions from microbial peat oxidation. Whereas the costs of rewetting may initially be high, on the longer run rewetting will always be preferable.

2.6 Conflicts and synergies

This chapter has provided an overview of various peatland utilisation and development options. Some options and aims are compatible whereas others conflict with each other (Table 2).

As Table 2 shows, paludiculture and abandonment represent the extremes of peatland utilisation in relation to the aims of production, biodiversity conservation, climate change mitigation and fire hazard reduction. Paludiculture is compatible with all aims, whereas abandonment conflicts with all regarded aims. Abandoned, drained peatlands are unproductive and useless for human welfare, are a constant source of greenhouse gases and a perennial risk of fires, whose haze has direct and indirect impacts on the economy and on human health.

Rewetting of peatlands is an extremely effective method to prevent peat fires and reduce GHG emissions. Rewetting should thus be an integral part of any regular peatland management.

Table 2. Conflicts and synergies of various peatland utilization options. Red = conflict; green = synergy (changed after Abel *et al.*, 2011)

Aim / Utilisation option	Production	Biodiversity conservation	Climate change mitigation	Fire hazard reduction
Paludiculture	synergy	synergy	synergy	synergy
Conservation	conflict	synergy	synergy	synergy
Rewetting	conflict	synergy	synergy	synergy
Peat extraction	synergy	conflict	conflict	synergy
Conventional agriculture	synergy	conflict	conflict	synergy
Conventional forestry	synergy	conflict	conflict	synergy
Abandonment	conflict	conflict	conflict	conflict

Long-tailed orange tip, found in peatswamp forest in Sarawak, Malaysia.
Photo: Marcel Silvius

3. Finance options

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Conservation, rehabilitation, and sustainable use of peatlands will need to be financed. With international climate change policy moving from the Kyoto framework to a more inclusive international regime, a wide spectrum of financial options are emerging. This chapter provides an overview of these sources of finance and their suitability for peatland conservation, rehabilitation, and sustainable use. The report focuses on climate finance and on finance options in the EU, as the EU stands out for both its integrated climate policy and its exposure to peatland related greenhouse gas emissions. Financial sources beyond the climate change framework, e.g. multilateral mechanisms to enhance sustainable water management or to protect biodiversity, are only presented in general terms. A summary of finance options is presented in Table 3.

Table 3. Summary of climate finance for peatland conservation, rehabilitation and sustainable use

Status of finance opportunity	Climate finance opportunities for peatland activities	
	Developing / non-Annex I countries	Industrialized / Annex I countries
Current and operational	**REDD+ capacity building and planning:** Significant bilateral and multilateral funding for REDD+ readiness. Mostly directed at national governments.	**Accounting under Art 3.4 of the Kyoto Protocol:** Expanded accounting options for Annex I countries which may create domestic policies and measures to protect or restore peatlands.
	Current CDM: Scope limited to afforestation and reforestation projects on peatlands but very limited demand for credits.	**Voluntary market:** Wide scope for all activities including re-wetting. Double counting can easily be avoided by cancelling Kyoto units for any relevant voluntary market projects. Weak demand for credits.
	Voluntary market: Wide scope for afforestation, reforestation and REDD+ (including re-wetting). Weak demand for credits.	
Recognized but additional decisions needed and not yet operational	**REDD+ market mechanisms and results based finance:** The need to finance emission reductions or removals under REDD+ recognized but details still being negotiated.	**Joint Implementation (JI):** Current JI rules prevent most JI LULUCF projects. A CMP decision needs to change JI rules to include LULUCF projects that decrease emissions by sources.
	NAMAs: NAMAs have been proposed and could include peat projects. Some finance is starting to flow to NAMAs but further work is needed to fully implement the NAMA concept and identify sufficient sources of finance.	**Domestic offsetting in the EU under the EU ETS:** Article 24(a) of the EU ETS allows for the creation of domestic offsets from a wide range of activities that could include peatlands. However the EC still has to make this, including the inclusion of LULUCF offsets operational.
	Green Climate Fund: The Green Climate Fund has been established but is not yet financed or operational. Finance for peatlands should be within its mandate.	**EU Policies:** The post 2012 Common Agricultural Policy (CAP) includes a set of proposals to shift focus to environmental protection and low-carbon policies. This includes a proposal to allocate 30% of the budget for direct payments to farmers to support measures beneficial to climate and the environment. Other EU policies that may support (and already have supported massive) peatland rewetting are the EU Water Framework Directive and the EU LIFE-Programme.
May be possible but additional decisions needed	**Expanded CDM:** There is a SBSTA work program to expand eligible LULUCF projects which could extend to peat.	

3.1 Reducing emissions from peatlands within the UNFCCC framework

Recent developments under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol (KP) have produced several options for reducing emissions from peatlands and leveraging finance in the short- and mid-term. For **developed (Annex I) countries** (3.1.1), the Durban outcome (CMP 7) allows for optional accounting of wetland drainage and rewetting. It remains to be seen whether the expanded accounting framework will also facilitate a change in the rules for Joint Implementation (JI) to allow for JI to be used to finance peatland restoration projects. For **developing (non-Annex I) countries** (3.1.2), progress on methodological issues and financing related to reducing emissions from *deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks* (REDD+), holds opportunities for integrated peatland interventions. The emerging climate finance concept of nationally appropriate mitigation actions (NAMAs) and cooperative approaches to agriculture are promising incentives for actions to reduce emissions from peatlands as well. Even the Clean Development Mechanism (CDM), thus far an instrument limited to afforestation and reforestation, may slowly change. The land use, land-use change and forestry (LULUCF) and peatland related changes in the international regulations have been kick-started by developments in the voluntary markets, in particular the Verified Carbon Standard (VCS), which over recent years has offered respectable solutions to many of the technical challenges LULUCF projects face (see Chapter 3.3).

Developed countries in the Annex I

(a) The Kyoto Protocol

From 2013 onwards, coinciding with the second commitment period of the Kyoto Protocol, Annex I Parties to the UNFCCC are given the opportunity to account for greenhouse gas (GHG) emissions by sources and removals by sinks resulting from “Wetland Drainage and Rewetting” (WDR) under Article 3.4 of the Kyoto Protocol. This means that Annex I countries can use peatland rewetting to meet their emissions reduction targets. This milestone was achieved at COP17 (2011) in Durban[1]. With this decision, peatlands and organic soils are at last recognized by the international climate change regime as an accountable factor and potential target for mitigation action.

WDR deals with a change in hydrological management of organic soils and applies to all land that has been drained and/or rewetted since 1990, unless that land is already being accounted for under another land use activity. The activity WDR is not limited to the category ‘Wetlands’, but is applicable to all land that is not being accounted for under other activities of the Kyoto Protocol.

The potential to account for emissions or removals from WDR creates incentives for a country to use domestic sources of finance to reduce emissions or increase removals from peatland.

COP 17 in Durban furthermore decided that, in contrast to the first commitment period (2008-2012), ‘forest management’ will be mandatory for accounting in the second commitment period (2013-2017). This means that drainage and rewetting of peatlands used for forestry in Annex I Parties must now be accounted for under the Kyoto Protocol. Accounting of grazing land management and cropland management remains voluntary.

(b) Joint Implementation (JI)

The Joint Implementation mechanism allows Annex I Parties[2] to fulfill part of their Kyoto commitments through financing emission reduction projects in another Annex I country. With respect to peatland conservation and restoration, some fine-tuning of the rules is, however, appropriate.

[1] Decision 2/CMP.7 (Land use, land-use change and forestry), Annex, para. 6.

[2] To be more precise: all Annex I Parties of the UNFCCC which are also “Annex B” Parties of the Kyoto Protocol. This includes all Annex I Parties except Turkey, Belarus and Kazakhstan, and for reasons of non-ratification of the Kyoto Protocol, the United States.

Dam built by Wetlands International in channel at Mentangai, Central Kalimantan, Indonesia
Photo: Marcel Silvius

First, the JI Guidelines[3] suggest that projects can only generate credits if they sequester carbon (as opposed to reduce emissions)[4]. This would imply that the stabilization and reduction of GHG emissions from drained peatlands could not translate into an eligible JI project activity. Second, the JI accounting and reporting rules state that JI LULUCF projects need to convert Removal Units (RMUs) into Emission Reduction Units (ERUs) - i.e. they cannot convert Assigned Amount Units (AAUs) into ERUs as is the case with other JI (non land use) projects[5]. Under Kyoto accounting rules RMUs are only issued if there is net sequestration of carbon[6]. Thus, where RMUs are not available, a peatland JI project, even if only reduced to its functioning as carbon sink, could not generate ERUs. These rules thus imply that most climate gain from peatland conservation and rewetting is not eligible as a JI project activity; in peatland projects the most important climate gain comes from reducing emissions (by retarding or stopping peat oxidation) rather than from carbon sequestration (re-installed by renewed peat accumulation), which is a much slower process.

A last challenge to solve is the very limited experience that the practitioners, project developers and the policy makers and regulators often have regarding JI and LULUCF. Notably the Joint Implementation Supervisory Committee which sets the rules for the centrally organized JI track could benefit from capacity development.

Opening JI for peatland conservation and restoration projects requires that the JI Guidelines and the accounting and reporting rules be changed to allow for (i) inclusion of LULUCF projects that reduce emissions; and (ii) conversion of either RMUs or AAUs into ERUs. The revision of the JI Guidelines, foreseen for COP 18 in Quatar in late 2012, is an opportunity to make way for these changes. Concerning the lack of practice, developments in the voluntary market should help inform methodologies to be used under JI.

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[3] Decision 9/CMP.1 *Guidelines for the implementation of Article 6 of the Kyoto Protocol*,

[4] See Decision 9/CMP.1 *Guidelines for the implementation of Article 6 of the Kyoto Protocol*, para 4 which only refers to enhancing removals by sinks under Article 3.3 and 3.4. See also Appendix B to this Decision, on project baseline calculation which limits the eligible sectors to those mentioned in Annex A of the Kyoto Protocol (which excludes LULUCF) and „anthropogenic removals by sinks".

[5] UNFCCC Decision 14/CMP.1 *Standard electronic format for reporting Kyoto Protocol units, Annex, Standard electronic format for reporting of information on Kyoto Protocol units*, para 13.

[6] Decision 13/CMP.1, *Modalities for the accounting of assigned amounts under Article 7, paragraph 4, of the Kyoto Protocol*, Annex, para 25.

Developing (non-Annex I) Countries

(a) The Clean Development Mechanism (CDM)
The CDM can be used to generate Certified Emission Reductions (CERs) from climate-friendly projects in developing countries. The CDM currently limits LULUCF activities to afforestation and reforestation projects, which also currently refers to credits only being generated by net removals by sinks[7]. This could include afforestation and reforestation of wet peatlands (e.g. with swamp forest tree species). Conservation, rehabilitation and improved management of non-forested peatlands are currently not eligible under the CDM. There is however scope for future expansion of LULUCF activities after a recent request at CMP7 in 2011 to initiate a work programme on this, with a draft decision planned for CMP9 in 2013[8]. This request creates an opportunity to include more types of emissions reductions from peatlands in the CDM. The current rules to account for permanence (i.e. the loss of carbon stock after a credit has been issued for the removal) have also caused problems for CDM afforestation and reforestation projects[9]. Applying the same rules to new CDM LULUCF project activities would create similar problems for the new activities. However, the permanence rules for afforestation and reforestation are currently being re-visited[10].

(b) Reducing Emissions from Deforstation and Forest Degradation (REDD+)
REDD+ is currently focused on forests so can apply to forests on peatland. REDD+ activities in peatlands are those activities that reduce or prevent greenhouse gas emissions by protection of forest on un-drained peat and by rewetting and revegetation of drained peat forests. In the tropics peat swamp forests are being drained and cut at an alarming rate. REDD+ is therefore a promising framework to finance emissions reductions from peatlands. There is significant mitigation potential in several countries, in particular Indonesia, Malaysia, Brazil, Papua New Guinea, Vietnam, Thailand and in other countries rich in peatswamp forests that have not yet been subject to large-scale peat swamp deforestation and degradation (see Chapter 5 and Joosten, 2009a).

REDD+ negotiations are progressing rapidly and multilateral and bilateral funding is readily available for capacity building and technical assistance. Long term finance of REDD+ performance is, however, still under negotiation. A number of options exist for interim results-based finance (i.e. payments for reducing emissions and increasing removals) including the World Bank's Forest Carbon Partnership Facility and bilateral support from the governments of Norway and Germany amongst others.

More work is also needed on some methodological issues, though solutions do exist. One of the methodological challenges for REDD+ is the inclusion of the peat/soil carbon pool in REDD+ reference /reference emission levels - the benchmark that will be used to assess performance and results-based finance. COP17 adopted a decision[11] on methodological guidance for REDD+, which states that countries that wish to participate in the REDD+ should include all significant carbon pools and activities, i.e. also organic soils, in their reference level. Including organic soils will enable generating significant emission reductions and potential finance if the country is able to reduce peat emissions from peatlands (which may require re-wetting drained peatlands). If the area of drained peatland, however, keeps expanding, or already drained and emitting peat swamps are not re-wetted, the significant and potentially increasing emissions from peatlands may swamp emission reductions from other pools, effectively eliminating the prospects of receiving results-based REDD+ finance.

[7] Decision 5/CMP.1, Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol, Annex, para 1 (definitions) and elsewhere.

[8] Decision 16/CMP.1. Land use, land-use change and forestry, para. 13.

[9] These rules require a type of temporary credit for CDM afforestation and reforestation projects that contain inherent risks and unattractive to most buyers.

[10] Decision 2/CMP.7. Land use, land-use change and forestry, para. 7.

[11] Decision 12/CP.17. Guidance on systems for providing information on how safeguards are addressed and respected and modalities relating to forest reference emissions levels and forest reference levels as referred to in decision 1/CP.16.

In 2012 decisions will be negotiated on methodological guidance for Measuring, Reporting and Verification (MRV), for national forest monitoring systems and for addressing drivers of deforestation and forest degradation. This guidance should include specific guidance on organic soils; see recommendations at the end of this Chapter.

(c) Nationally Appropriate Mitigation Actions (NAMAs)

NAMAs seek to scale-up developing country ambitions by matching comprehensive, results-based mitigation interventions with adequate climate finance, technology support and capacity building. NAMAs - open to all mitigation sectors - provide an important vehicle for broad management of organic soils and wetlands, allowing the combination of conservation, restoration and good practices into a coherent program. COP17 reiterated the invitation to all developing countries to submit NAMA proposals that will seek international funding. COP17 further clarified the key components for NAMA reporting which includes the identification of a national implementing entity, a projection of costs and time, the amount and type of international support required, an estimate of emission reductions to be achieved, and other indicators of implementation. There is no deadline for NAMA submissions, yet the earlier a country positions itself for NAMA interventions, the more accessible it becomes for potential funders, ranging from developed countries to international development agencies and banks, to private sector entities.

While the NAMA concept is still emerging it is expected that any peatland related NAMA will have to be established using robust data and relying on stringent MRV which will still require considerable effort and time. To date, developing countries are attracting bilateral donors for NAMA feasibility studies and NAMA pilots across sectors. This funding should extend to peatland NAMAs.

The following countries have considerable GHG emissions from peatlands (Joosten, 2009a) and could consider developing peatland NAMAs: Indonesia, Malaysia, China, Mongolia, Myanmar, Angola, DRC, Guinea, Kenya, Madagascar, Mozambique, Sudan, Uganda, Zambia, Brazil, Cuba, Guyana, Honduras, Mexico, Venezuela, Bangladesh, Thailand and Vietnam.

(d) Green Climate Fund (GCF)

The Green Climate Fund (GCF) is expected to become the central multilateral fund for climate change. It will channel a significant portion of the annual $100 billion that developed countries have committed to mobilize from both public and private sources by 2020 to support climate activities in developing countries. Once operational, the GCF will fund both mitigation and adaption activities. Its operation should extend to activities that support the conservation, rehabilitation, and sustainable use of peatlands in developing countries. The details of how the GCF will disburse funding is still being determined, but will include direct access to the GCF by developing country governments, funding to NAMAs and funding of private sector initiatives. The GCF could explicitly cover opportunities for peatland projects given the disproportionate role of peatlands in climate change, but it is unclear if

Box 5: Building land use NAMA's: example from Indonesia

In September 2011 Indonesia issued a presidential decree on land-based NAMA's, combining REDD+, peatland emission reductions, restocking of above- and below ground carbon pools regardless of forest/non-forest status of the land, and reduction of methane and nitrous oxide emissions from agriculture (Presidential Decree No. 61 of 2011). This likely makes Indonesia the first Non-Annex-I country in the world to have such a holistic perspective on emissions from the land-based sectors. The presidential decree gives substance to the country's NAMA commitments to reduce its 2020 emissions by 26%. Within 12 months of issuance all districts and cities (more than 400 in total) are meant to provide their own action plans within the sectoral priorities that were established at national scale.

the GCF will be operated with this level of specificity. Alternatively, if the GCF decisions do not identify specific sectors to fund Parties and observers will at least need to ensure that the GCF remains broad enough to include peatlands.

(e) Adaptation

The UNFCCC adaptation framework may facilitate peatland-related assistance and funding, in particular for least developed countries (of the NAMA list above: Myanmar, Angola, DRC, Guinea, Madagascar, Mozambique, Sudan, Uganda, and Zambia), which receive on-going support with developing their National Adaptation Plans (NAPs). Other current and future adaption funding may be available for peatland conservation or restoration, though it should be noted that adaptation has traditionally been chronically underfunded. The GCF is, however, meant to provide a new and additional source of funding for adaptation.

(f) Agriculture

Agriculture has been very slow in being incorporated into the negotiations for the next climate change agreement. Discussions are ongoing in the Ad Hoc Working Group on Long-term Cooperative Action under the Convention on the establishment of a technical work programme for agriculture in SBSTA. This would be the first step towards inclusion of agriculture into the future climate mechanism. Organic soils and peatlands are agro-ecosystems with large mitigation potential and thus merit particular attention in the Agriculture programme.

3.2 Climate initiatives for peatlands under the European Union

The EU did not include LULUCF activities in the European Emissions Trading Scheme (EU ETS), adopted in 2003[12] nor in the 2008 climate and energy package which defines the EU's climate policy for the period up to 2020. However, the European Commission acknowledged that LULUCF activities have a substantial impact on overall emission across the European Union (see alsoChapter 5) and that there is the potential for substantial emission reductions[13].

EU Accounting for LULUCF

In March 2012, the European Commission adopted a legislative proposal[14] for a Decision of the European Parliament and the Council to establish, for the first time, accounting rules for GHG emissions and removals in the land use sector. Accounting for emissions and removals from afforestation, reforestation, deforestation, forest management (FM), cropland management (CM) and grazing land management (GM) are proposed to be mandatory. Member States can opt to account also for emissions and removals from revegetation and "wetland drainage and rewetting" (WDR). The European Commission sees this move as a "first step towards incorporating removals and emissions from forests and agriculture in the EU's climate policy". There is a risk, however, that Member States will not accept mandatory CM and GM for similar reasons as they have refrained from choosing voluntary CM and GM in the first commitment period. In that case countries will (except in mandatory forestry) not be able to use the huge mitigation potential of organic soils in the land use sector (see Chapter 5), unless accounting for WDR becomes mandatory or is voluntarily chosen. In fact WDR was explicitly created as an option to address the peatland hotspot effectively in case FM, CM and GM would not be accounted for. If FM, CM and GM would be accounted for, 90% of the peatland emissions would be covered and WDR would be largely redundant. That said, the Commission's proposal has come a long way from a decade of LULUCF-neutral policy-making. The adoption of LULUCF-related targets within the Effort Sharing Decision (which establishes GHG emission targets outside the EU ETS) or even within the EU ETS, may well follow in the mid-term (prior or after 2020).

[12] Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community.

[13] See most recently in the justification for the accounting proposal, Proposal for the Decision of the European Parliament and of the Council on accounting rules and action plans on greenhouse gas emission and removals from activities related to the land use, land use change and forestry, COM(2012) 93 final of 12 March 2012.

[14] Ibidem.

EU Domestic Offsetting
A further move may consist in promoting LULUCF-related activities as domestic offsetting (DO) projects, an option the EU ETS offers as of 2013 (Article 24(a) of the EU ETS). In principle, DO projects are open to any projects "that reduce greenhouse gas emissions not covered by the Community scheme". As the strict mirroring of EU ETS and Kyoto accounting is fading, there seems to be no Kyoto related limitation to offsetting projects from peatland whether or not an EU Member State chooses to account for wetlands or not.. Thus far, there has been little activity by the European Commission to operationalize Article 24(a). This may be explained - at least in part - by the growing surplus of allowances and credits available for compliance under the EU ETS. However, EU Member States are increasingly supportive of a new DO mechanism and several of them have launched national pilots on the matter.

EU Common Agricultural Policy (CAP)
The Common Agricultural Policy (CAP) is the cornerstone of EU policy making in agriculture and agro-forestry. The CAP includes the bloc's largest subsidy scheme. Introduced in 2003[15], the so-called cross-compliance mechanism ties EU support for farmers to compliance with standards of environmental care, public and plant health and animal welfare. Farmers are, among others, required to avoid the deterioration of the habitat, maintain soil organic matter (a condition that perversely not applies to peatlands because the criteria only match mineral soils, so that agriculture on deeply drained peat still receives unrestricted EU direct payments) (Wichtmann and Wichmann, 2011) and protect and manage water. Non-compliance should lead to reductions in subsidy and development payments. For the CAP post 2012 the European Commission has adopted a set of legislative proposals that include a shift of focus to environmental protection and climate change mitigation. Proposed measures include an allocation of 30% of the budgetary envelope for direct payments to farmers to support measures beneficial to climate and the environment[16]. Legislative discussions are ongoing with a final decision by the legislative bodies, Parliament, and Council, being expected by 2013. If approved and effectively implemented, the regulation on direct payments may become a strong incentive for peatland conservation and restoration.

3.3 Voluntary carbon market

The voluntary market was valued at $394 million in 2010, which is significantly smaller in value compared to the compliance market which was valued at $141.9 billion in 2010 (Linacre *et al.*, 2011). However, the voluntary market is the only carbon market to date that recognizes and is able to provide direct finance for peatland projects. This makes it an important finance instrument and testing ground for technical options to account for emissions and emission reductions and practical challenges of implementation.

In March 2011 the Verified Carbon Standard (VCS), the dominant voluntary standard with 34% of recorded transactions in 2010, published its new guidance for land use projects that included the new project category Peatland Rewetting and Conservation (PRC). The PRC category allows for two main types of peatland projects: Rewetting of Drained Peatland (RDP) and Conservation of Undrained or Partially drained Peatland (CUPP). Both types may be combined with existing land use categories under the VCS.

Increasing the relevance of the voluntary market for peatland projects will require additional methodologies to be developed and additional on-the-ground experience on developing and implementing peatland re-wetting projects to be gained. Chapter 4.4 of this report addresses some technical issues with developing peat projects and how these are resolved under the VCS. The biggest challenge with the voluntary market (and carbon markets generally) is the weak demand for credits.

[15] Council Regulation (EC) No 1782/2003, subsequently repealed by Council Regulation (EC) No. 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers, also amending Regulations (EC) No 1290/2005, (EC) No 247/2006, (EC) No 378/2007.

[16] Proposal for a Regulation of the European Parliament and of the Council establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy, COM(2011) 625 final/2, 19 October 2011.

Box 6: Emissions reductions from peatlands in Belarus through the Voluntary market

Peatlands cover 2.9 million hectares (14%) of Belarus. Between 1960 and 1990 half of the country's peatlands - some 1.5 million hectares - were drained, in most cases to make way for agriculture. Today vast areas of the once cultivated land sit idle, while the drainage system, in most cases, has never been reversed. As a result Belarus ranks among the top eight countries, when it comes to CO_2 emissions from degraded peatlands.

Sponsored by UNDP and GEF (2006-2010) as well as the German Ministry of Environment (BMU) and KfW (2008-2012), approximately 36,000 hectares of peatland have been restored (Tanneberger & Wichtmann 2011a). Based on the criteria of accessibility, costs and carbon intensity, the program led to the identification of an additional area of 30,000 hectares found most suitable for carbon project development. According to conservative estimates, a carbon project consisting of rewetting these 30,000 hectares, together with 18,000 hectares that had already been rewetted, would generate some 100,000 tCO_2 eq. annually over the next 10 years.

Key elements for the establishment of a VCS carbon project were (i) developing a methodology; (ii) finance (including cash-flow), (iii) governance and regulatory aspects, and (iv) operations. A 2011 calculation of costs for engineering, works, maintenance and the carbon cycle estimated a cost of about 5 million Euros over ten years, putting the generation costs at around 5 Euros per credit. The need for ecologic (and carbon) stabilization after rewetting makes the first verification viable only about five years after the start of rewetting activities. This means that the first credits can be issued only in year 5 or 6. As a result most emission reductions and, hence, credits, will be generated between year 5 and year 10. This means a substantial part of the project costs need to be advanced before revenues are generated and the project is able to break-even. This requires long-term engagement from investors for ten years or longer.

On the legal, regulatory and institutional side, Belarus can rely on a clearly defined land title and legislation. The Government holds the property and all derived titles over the sites identified for the project and there is a centrally organized institutional structure set within a legislative framework dedicated to voluntary emission reduction projects. However, uncertainties remain, most notably on the power for any Government entity to confer carbon title to the project entity ("initiator" under Belarusian legislation), on the responsibilities among Government institutions including at the regional and municipal level, and uncertainties regarding taxation, especially for monies made available as advance payments.

The operational priority lies in identifying, or creating, a project entity with sufficient operational, institutional and professional capacity to handle 30 and more sites, pursue the project through two project cycles, negotiate with the Belarusian authorities and a foreign investor, and be responsible for the discharge and distribution of the carbon revenues. Various options, ranging from a privately organized off-spin of a local non-government organization to a state-owned forestry company to a joint venture of different actors (possibly including the foreign investor) have been scrutinized and discussed with the Government as the ultimate seller of carbon credits and the foreign investor as the buyer. The creation of a joint venture, organized as a limited company, was held to be the strongest option.

The preparation of the project, including the creation of a project entity, is currently under way. Once the transaction is finalized, the Belarusian peatlands may well generate the first voluntary carbon credits from a peatland project in Europe if not worldwide.

Weak demand is not, however, a lack of demand. Demonstrating high co-benefits such as biodiversity, other environmental services and social benefits will help projects attract finance. Peatland projects that also fall under the REDD+ umbrella may be able to find finance and markets for voluntary emission reductions under international REDD+ finance.

Harvest of reed for roofing from dutch fen peatlands.
Photo: Hans Joosten

3.4 Global Environmental Facility (GEF)

The Global Environmental Facility (GEF, http://www.thegef.org/gef/climate_change) offers various possibilities to finance conservation of existing peatlands and restoration of degraded lands. The main opportunities for support are within the focal areas climate change mitigation, sustainable forest management/ REDD+, and land degradation and under the Least Developed Countries Fund and the Special Climate Change Fund Framework Adaptation to climate change. GEF supports the implementation of three conventions, CBD, UNFCC and UNCCD relevant to peatlands or organic soils. Work aiming at supporting the conservation and restoration and sustainable use of peatlands and organic soils can come under any of these conventions.

A defining feature of GEF funding is that is always requires co-funding, which under GEF 5 is 80%. Another central feature is that GEF always funds country led initiatives.

The overall goal of the GEF in climate change mitigation is to support developing countries and economies in a transition to move towards a low-carbon development path. One area of work is the promotion of the conservation of carbon stocks through sustainable land management. GEF also supports creating benefits for local economies and their environmental conditions. This can offer interesting possibilities for peatland conservation and restoration.

With respect to sustainable forest management and REDD+, the GEF focuses particularly on the implementation phase of REDD+ by supporting the following activities: developing national systems to measure and monitor carbon stocks and fluxes from forests and **peatlands**, strengthening forest-related policies and institutions, developing policy frameworks to slow the drivers of carbon emissions from deforestation and forest degradation, establishing innovative financing mechanisms and piloting projects to reduce emissions from deforestation and forest degradation. In addition, the GEF is strongly supporting work with local communities to develop alternative livelihood methods to reduce emissions and sequester carbon.

The GEF focal area to combat land degradation aims to contributing in arresting and reversing current global trends in land degradation, specifically desertification and deforestation, by addressing emerging issues for sustainable land management in rural production landscapes. The strategy embodies the landscape approach and the ecosystem management principle to maximize integration with other GEF focal areas on Biodiversity, Climate Change, and International Waters.

The following four objectives form the basis of the strategy:

1. Maintain or improve a sustainable flow of agro-ecosystem services to sustaining the livelihoods of local communities.
2. Generate sustainable flows of forest ecosystem services in arid, semi-arid, and subhumid zones, including sustaining livelihoods of forest-dependent people.
3. Reduce pressures on natural resources from competing land uses in the wider landscape.
4. Increase capacity to apply adaptive management tools in sustainable land management.

3.5 Policy recommendations to overcome obstacles to finance options

A wide range of opportunities for financing emissions reductions through the conservation, rehabilitation, and sustainable use of peatlands exist or are in development. Here we provide recommendations to progress using existing options and making additional necessary decisions.

Annex I accounting rules for LULUCF
Annex-I countries with significant peat soils are recommended to elect Wetland Drainage and Rewetting (WDR) to enable projects to reduce emission from peatlands.

Joint Implementation
As current rules prevent JI from financing Wetland Drainage and Rewetting projects, the rules must be widened so that JI projects can reduce emissions in addition to enhancing removals, and by allowing AAUs or RMUs to be converted into ERUs.

The Clean Development Mechanism (CDM)
In order for the CDM to become a more useful finance tool for peatland projects the range of eligible activities needs to be expanded to include conservation, rehabilitation and improved management of non-forested peatlands. The CDM rules on accounting for permanence also need to be revised. Credible options include the use of insurance and/or buffer pools[17] - a concept already in use in the VCS and other voluntary standards.

REDD+
REDD+ countries need technical support to ensure organic peat soils are properly included in a country's reference emission level or reference level developed for REDD+ activities. National plans and international financial support also needs to be in place to address these emissions, otherwise countries will have a significant incentive to either ignore peat emissions or abandon REDD+ entirely.

[17] Buffer pools require projects to contribute a certain amount of credits into a (shared) pool. If a project loses carbon stock credits can be cancelled from the buffer to ensure overall environmental integrity in the system.

Nationally Appropriate Mitigation Actions (NAMAs)
Developing countries that have peat soils should develop and submit projects or activities to protect, restore, or sustainably manage their peat as a NAMA. This is particularly relevant for peatlands that do not qualify as forest and would therefore fall outside of REDD+.

EU accounting
The European Commission's proposal on LULUCF accounting may be strengthened through making the accounting for wetland drainage and rewetting mandatory across Member States. Most importantly, however, the respective legal acts should be adopted promptly so that measures are in place before 2013. A further measure to bring LULUCF and peatland activities within the scope of emissions trading beyond the EU ETS would be to cover them by the Effort Sharing Decision and thus make them part of Government commitments. Again, this may well happen before 2020 and should be prepared through a separate proposal by the European Commission.

Domestic Offsetting in the EU
Domestic offsetting under Article 24(a) of the EU ETS should be promulgated by the European Commission over the next couple of years and efforts to develop national plans to facilitate offsetting projects (something several Member States already do for other economic sectors) should be supported.

EU Common Agricultural Policy
First steps towards the conservation and the sustainable use of peatlands have been made with the recent legislative proposals from the European Commission. Still, the legislator, the Council and the European Parliament, still need to adopt these proposals. Once this is done, a concrete framework for peatland conservation, rewetting and more sustainable management needs to be put in place to make the best possible use of any financial incentives available.

Voluntary market
Further work is needed to develop more methodologies for peatland projects along with on-the-ground experience implementing them. This will come with time and financial support from voluntary buyers. Links between accounting/MRV using voluntary market standards and NAMAs should be explored.

In all cases, the potential to increase supply should be met by an international and national demand for these new credits from Annex I countries, something which is potentially a challenging task.

Peatlands research in Tierra del Fuego, Argentina.
Photo: Hans Joosten

4. MRV and practical solutions

John Couwenberg, Marcel Silvius, Susanna Tol & Hans Joosten

In recent years, much progress has been made in quantifying greenhouse gas fluxes from peat soils. Credible methods for measuring, reporting and verifying (MRV) emissions and emissions reductions from peatlands are available and various assessment methodologies are under development and being tested. The Intergovernmental Panel on Climate Change (IPCC) provides methodological guidance and as a result of scientific progress, a supplement to IPCC 2006 guidelines with respect to Wetlands and organic soils will be ready for adoption by the UNFCCC Conference of Parties in 2013.

This Chapter provides an overview of available methodological guidance and data for quantifying greenhouse gas emissions from organic soils. To address concerns of countries with regard to accounting and MRV, this Chapter also provides practical information on technical issues such as the definition of 'organic soils', lack of area and activity data and double counting in compliance and voluntary markets. Furthermore it discusses important safeguards to be taken.

Box 7: Where to find information on organic soils in your country?

Most countries possess information about the occurrence of peatlands and organic soils in their country. Important national and local sources to consider are

- National Soil Surveys
- National Geological Surveys
- Research institutions of relevant former colonial powers
- Land tax authorities
- Chambers of agriculture
- National forest agencies
- National environmental or natural resources agencies
- National statistics agencies
- Stakeholder organizations (conservation, agriculture, forestry, peat extraction)
- Universities
- Sector experts

International data sources to consider include

- ISRIC World Soil Information: http://www.isric.org/
- International Mire Conservation Group (IMCG) Global Peatland Database: http://www.imcg.net/pages/publications/imcg-materials.php?lang=EN
- Ramsar Wetland Data Gateway: http://sedac.ciesin.columbia.edu/ramsardg/
- WWF Global Lakes and Wetlands Database: https://secure.worldwildlife.org/science/data/item1877.html
- UNEP-WCMC Wetlands database: http://www.unep-wcmc.org/
- International Peat Society: http://www.peatsociety.org/

Surprisingly much information - be it rather disperse - can also be found in the scientific literature, especially with respect to soils, geology, wetlands and palaeoecology. Not to be forgotten is the grey literature in the above-mentioned institutions.

4.1. What are peatlands and organic soils

Organic soils are soils with a substantial layer of organic matter at or near the surface. According to the 2006 IPCC Guidelines, soils are organic if they satisfy the requirements 1 and 2, or 1 and 3 below:

1. thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm;
2. soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter); and
3. soils are subject to water saturation episodes and have either:
   a. at least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay; or
   b. at least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay; or
   c. an intermediate proportional amount of organic carbon for intermediate amounts of clay.

Box 8: Emissions from peatlands

In natural, undrained peatlands, plants capture CO_2 from the atmosphere by photosynthesis and fix it in plant material. After dying off, part of the dead plant material remains as peat and is under water logged conditions not further decomposed. Natural peat forming peatlands are a sink of CO_2 from the atmosphere. However, the high water levels, necessary for the conservation of large part of the dead plant material as peat, also stimulate the production of methane by microbes that are able to decompose fresh plant litter in the absence of oxygen. Methane produced in the waterlogged part of the soil can partly be oxygenated when it moves upward towards the atmosphere. Methane may bypass the oxygenated upper soil layer, however, by moving through the interior of vascular plant species. Plants that provide for such a shortcut or shunt between the root zone and the atmosphere are referred to as "shunt-species". Combined, the CO_2 and CH_4 fluxes from natural, undrained peatlands, result in a radiative forcing that - dependent on peatland type - is slightly positive or slightly negative on the 100 yr timescale. On the long run, all natural peatlands sequester carbon from the atmosphere and are climate coolers.

Nitrous oxide (N_2O) is formed in peatlands when inorganic nitrogen is made available through peat decomposition (mineralisation), through fertilizer application or through nitrogen deposition. Nitrous oxide emissions are associated with lowered water tables. In deficiency of nitrogen, undisturbed peatlands may act as a sink of N_2O.

When peatlands are drained, oxygen penetrates the soil causing rapid decomposition of the peat, and peatlands become a major source of greenhouse gases. Whereas CH_4 production ceases under the presence of oxygen, lowered water tables result in the loss of soil carbon, which is for a large part emitted as CO_2. Drained peatlands are a source of CO_2 to the atmosphere. Net CO_2 efflux rates from drained peat soils are on average an order of magnitude higher than the rate of CO_2 uptake in undrained sites. This strong negative climate effect of drained peatlands is often intensified by concurrent emission of the more potent greenhouse gas N_2O. Moreover, drainage associated fires increase emissions substantially. Because of peat oxidation and physical compaction, the drained peatland surface will lower over time, so-called peat subsidence.

Peatland rewetting reduces the emissions from drained peatland: CO_2 and N_2O emissions strongly decrease, whereas CH_4 emissions increase but generally less substantially. In cases that abundant fresh biomass (crops, mellow grass) is flooded, CH_4 emissions may increase to such an extent that the climate effect of CO_2 and N_2O emission reduction is annihilated. This is caused by dying off of non-wetland plants, producing copious rotting material. These 'transient dynamics' are of limited duration as the availability of easily degradable fresh biomass strongly decreases when wetland plants have re-established. On the mid- and long-term, rewetting of peatlands may therefore be expected always to lead to a net reduction of climate relevant emissions from the peat body compared with the drained baseline.

Annex 3A.5 in Volume 4 of the 2006 IPCC Guidelines offers criteria for the identification of organic (peat) soils based on the FAO (1998) key to soil types.

The 2006 IPCC Guidelines thus largely follow the FAO (1998/2006) definition of “Histosol” and link (and even equate) organic soils to peat soils. Indeed, apart from shallow (≥10 cm) organic-rich soils overlying ice or rock, organic soils (Histosols) are identical with peat and peaty soils of at least 40 cm total thickness within the uppermost 100 cm, containing at least 12 percent organic carbon (~20 percent organic material) by weight. This definition deviates from most European definitions of peatland in that it stipulates a slightly thicker organic layer and slightly lower organic matter content (Joosten and Clarke, 2002). IPCC (2003, 2006) omits the 40 cm criterion from the FAO definition to allow for country specific approaches. To conclude, it is possible to apply the standard definition of your country as long as it is consistently used.

4.2. Recent reviews of peatland emissions

Peatland GHG fluxes are dependent on a wide spectrum of site parameters that vary strongly over the year, including water level, temperature, vegetation growth and land use. These fluxes must be quantified for reporting and for accounting possible emission reductions. In recent years quantitative research into greenhouse gas fluxes from peat soils has advanced considerably (see e.g. Alm *et al.*, 2007; Maljanen *et al.*, 2010; Couwenberg, 2011; Couwenberg and Fritz, 2012; Couwenberg *et al.*, 2010, 2011; Hooijer *et al.*, 2010, 2012; Strack 2008 for reviews of emissions from boreal, temperate and tropical peatlands). The scientific progress has prompted the development of peatland carbon reporting and accounting schemes both under the UNFCCC and its Kyoto Protocol as well as on the voluntary carbon market.

4.3. IPCC guidance

The IPCC Guidelines that are currently in use in the UNFCCC and the Kyoto Protocol are the “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories”, the “Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)” and the “Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003)”. In 2006, the IPCCC furthermore produced the “2006 IPCC Guidelines for National Greenhouse Gas Inventories”. The use of these guidelines is not yet obligatory, but starting with the second commitment period of the Kyoto Protocol, the 2006 IPCC Guidelines do apply to those countries that have ratified the Kyoto Protocol. In the 2006 IPCC Guidelines an appendix provides (incomplete) guidance on wetlands, including on peatlands used for peat extraction. Emissions from drained organic soils are addressed already in the existing IPCC guidance, where emission factors are found for Forestland, Cropland and Grassland.

In 2010, UNFCCC invited IPCC to explore development of supplementary guidance on organic soils, particularly also addressing restoration and rewetting of drained peatlands. In response to this invitation IPCC is currently drafting its “Supplement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands”, to be finished in 2013. Two Chapters of the IPCC Supplement will address greenhouse gas emissions and removals from peatlands: Chapter 2 will provide cross cutting guidance on drained organic soils covering all land-use categories. The IPCC’s Supplement’s Chapter 3 will provide guidance on rewetted peatlands.

The supplementary Chapter on drained peat soils will address emission factors for drained organic lands covered under the land use categories of Forestland, Cropland, Grassland and Wetlands. A review of existing IPCC guidance on drained organic soils revealed considerable opportunity for improvement (Couwenberg, 2011). On the basis of recent scientific developments, the new Chapter will update existing methodologies and emission factors of the 2006 Guidelines and fill gaps where new insight allows. The Chapter will refine emission factors by including drainage classes that address the intensity of land use and will provide a wider geographical coverage, including tropical peat soils. Improved Tier 1 emission factors will be provided for CO_2 (Chapters 4 to 9 of Volume 4 of the 2006 IPCC Guidelines), CH_4 (Chapter 7) and N_2O (Chapter 11).

Agriculture on peatlands in Polessie, Ukraine.
Photo: Hans Joosten

Moreover, the Chapter will fill various gaps in the 2006 IPCC Guidelines by providing methodologies and emission factors for CH_4 emissions from drainage ditches as well as for indirect CO_2 emissions associated with water borne carbon losses from drained organic soils. In addition, guidance will be provided for the development of higher Tier methods to estimate GHG fluxes from drained peatlands, focusing on country-specific emission factors associated with, for example, differences in nutrient status and management practices.

The Chapter on rewetting and restoration of peatlands will cover all practices that restore the water table of a drained peatland back to a depth at which hydrological and biogeochemical processes characteristic of saturated soils are re-established. Only the rewetting caused by direct human activity, such as blocking drainage ditches or disabling pumping facilities, is considered. Whereas rewetting curbs the loss of CO_2 and N_2O to the atmosphere, the waterlogged conditions also introduce efflux of CH_4 for which no guidance was available in the 2006 IPCC Guidelines. The scientific basis for developing CH_4 emission factors is ample, however (Couwenberg and Fritz, 2012).

For tropical regions, evidence of successful rewetting of peatlands that restores the water table to the pre-drainage conditions observed in pristine peatlands was insufficient to provide a sound basis for the development of default emission factors. Flux measurements from pristine peatlands will be used to arrive at emission factors for re-wetted peatlands in these regions. Similarly, a comparison of GHG fluxes from undrained, pristine peatlands with fluxes from rewetted sites has shown that flux values are similar for most gases in temperate and boreal regions.

Guidance will be provided for the development of higher Tier methods to estimate GHG fluxes from rewetted peatlands, focusing on country-specific emission factors associated with, for example, differences in nutrient status, vegetation cover, management practices and time since rewetting. Moreover, water borne carbon fluxes may be addressed. Particularly with respect to CH_4 fluxes, prior land-use can influence fluxes from re-wetted peatlands when the presence of easily degradable organic material results in a transient period of excessive methane efflux. Changes in CH_4 emissions and removals over time are likely linked to vegetation succession and guidance will urge countries to include information on vegetation development.

Under Tier 1, N_2O emissions from rewetted peatlands will likely be deemed insignificant under the new IPCC guidance.

4.4. Guidance provided by the voluntary market

Until recently, voluntary carbon markets did not foster any peatland projects. In March 2011, the Verified Carbon Standard (VCS), the globally dominant standard with 34% of recorded transactions in 2010, published its new guidance for land use projects, including a new category of Peatland Rewetting and Conservation (PRC) projects. The PRC guidance allows for two main types of peatland projects: Rewetting of Drained Peatland (RDP) and Conservation of Undrained or Partially drained Peatland (CUPP). Both types may be combined with existing land use categories under the VCS programme.

The PRC requirements are part of the general VCS AFOLU requirements that provide guidance how projects can comply with the VCS standard. Based on these requirements, methodologies are developed that explain step-by-step how a project shall estimate its emission reductions or removals. Finally, project description or design documents fill in the specifics set out in a methodology document and provide information specific to the project. At present several methodologies are under development and accessible through the VCS website (www.v-c-s.org).

Conservation of Undrained or Partially Drained Peatland (CUPP) concerns activities that avoid drainage in undrained (or further/deeper drainage in partially drained) peatlands that are threatened by drainage. These activities aim at reducing CO_2 emissions by avoided peat oxidation and/or by avoiding increased fire incidence. Projects that continue or maintain active drainage are not eligible. Rewetting of Drained Peatland (RDP) concerns establishing a higher water level on drained peatland.

In peatlands, GHG emissions largely depend on hydrological conditions. Therefore, most PRC requirements relate to hydrology or to soil moisture-dependent processes. Projects must demonstrate that there is either no hydrological connectivity to adjacent areas, or that a buffer zone is established to ensure that adjacent areas will not significantly affect the project area and vice-versa. Alternatively, for RDP projects, "ecological" leakage must be accounted for in areas that are hydrologically connected to the project area (e.g. forests that die off outside the project area as a result of rewetting of the project area). PRC projects must further account for leakage due to activity shifting.

To quantify emission reductions, projects must establish an ex-ante baseline and a project scenario. The project scenario describes GHG fluxes in the project area and possible leakage emissions outside during the project crediting period, which typically spans 30 to 50 years. The baseline scenario describes what would have happened during this time in absence of the project measures. Both the baseline and the project scenario must be reviewed regularly and updated when necessary. The amount of emission reductions generated is calculated as the difference between project and baseline emissions.

GHG emissions for both the baseline and project scenarios can in the VCS-PRC be assessed using water level or another justifiable parameter as a proxy. Emissions of CH_4 from drained peatland are negligible and may conservatively be neglected in the baseline. Transient peaks of CH_4 after rewetting, however, necessitate the inclusion of CH_4 in the project emissions calculation. N_2O emissions also must be included. A methodology establishes the criteria and procedures by which the CH_4 and N_2O sources may be deemed insignificant (for which VCS has set specific rules) or may be conservatively excluded (based on a quantitative assessment or by using peer-reviewed literature).

Methodologies for Rewetting of Drained Peatland (RDP) projects explicitly addressing anthropogenic peatland fires must establish procedures for assessing the baseline frequency and intensity of fires in the project area.

PRC projects must demonstrate that their peat carbon stock is 'permanent'. The maximum quantity of GHG emission reductions that may be claimed by a project is limited to the difference in peat carbon stock between the project and the baseline scenario after 100 years. This limit is established because in peatlands that are not fully rewetted, the peat will continue to oxidize leading to GHG emissions and subsidence and possibly to a complete depletion of the peat. Moreover, continued degradation and subsidence of the peat may cause peat to be depleted in the baseline within the project crediting period. Projects may only claim emission reductions for the period in which peat remains present in the baseline. The current methodologies under development provide relatively simple procedures for estimating the depletion of the peat layer.

4.5. Practical solutions for challenges

Conservatism in case of uncertainty
Under the current UNFCCC reporting system, “estimates of emissions should be accurate in the sense that they are systematically neither over nor under the true value, so far as can be judged, and that uncertainties are reduced so far as is practicable” (UNFCCC, 2003).

Whereas the capacity for monitoring greenhouse gas fluxes from peatlands is rapidly increasing (see above), in some countries and situations (e.g. CH_4 emissions from recent rewetting, N_2O emissions from drained fen peatlands) the overall estimates may not yet be very accurate. In such cases “the principle of conservativeness” has to be applied and reductions should be estimated at the low side of the range. This means that the lowest reasonable emissions have to be used in the baseline accounting and the highest reasonable emissions in the commitment period.

The conservativeness principle is already applied in the Kyoto Protocol, e.g. in 16/CMP.1 (annex par. 21) and as a “punitive”’ instrument applied by reviewers in the adjustment procedure of the KP reporting. The conservativeness principle contributes to climatic integrity and provides a win-win option. It guarantees that accounting for emissions reductions from peatlands does not lead to fake emission reductions. On the other hand, the approach will stimulate countries to increase the quality of reporting and develop methodologies for assessing emissions and removals more accurately.

Difficulties with data availability and certainty have never led to exempt gases and sectors. In agriculture, for example, N_2O which is responsible for 6% of total GHG emissions in the EU-27 is accounted even with an uncertainty of around 100% (personal communication by Giacomo Grassi (JRC)).

Double counting
Double counting, sometimes also referred to as ‘double-monetization’, ‘double selling’ or ‘double-claiming’, is the double (or multiple…) selling of the same GHG emission reduction or removal under different standards or systems. Double counting is particularly relevant when voluntary market initiatives are developed in countries that are also subject to compliance market accounting (such as the Kyoto Protocol).

Most voluntary market standards - including the VCS - address this issue by requiring the cancellation or retirement of an equivalent number of credits from the compliance market before voluntary market credits are issued. This solution would also apply to the land use, land use change and forestry sector, including the new “Wetland Drainage and Rewetting” activity. If a Party chooses to elect to account for Wetland Drainage and Rewetting under Article 3.4 of the Kyoto Protocol during the second commitment period, it could cancel Kyoto units for any relevant voluntary market projects to avoid double counting. If a country chooses not to do this, the VCS and any other credible standard would simply stop issuing voluntary market credits. Similarly if the CDM were expanded to include Wetland Drainage and Rewetting, accounting rules would prevent both CERs and voluntary market credits being issued for the same project. In either case double counting between Kyoto Protocol and voluntary market standards can be readily avoided.

Lack of area and activity data
Countries may have concerns that they are not yet able to manage the necessary inventory and monitoring from peatlands and organic soils. A concern linked to this is that while such methods exist, they tend to be expensive.

Several assumed gaps in data availability do not exist or are not unique to peatlands. To monitor greenhouse gas fluxes from peatlands, you only need data on the extent and location of drained lands, organic soils and the relevant emission factors, not on the peat depth. The first data are easily available in Annex 1 countries as they are linked to land maps and information on land use activities that are well registered in developed countries. Data for abandoned lands can also be easily derived from the previous mentioned information on land use activities, because emissions continue after termination of land use until all peat is gone or the drainage system collapses.

The limited effort to improve the completeness of reporting data in Annex 1 countries was recognized by the European Commission in its recent legislative proposal on accounting rules for the land use sector. The proposal mentions that, as organic soils only make up 2% of the total land surface in the European Union, the additional efforts of improved completeness of reporting should be limited and therefore the first essential step could be taken rather swiftly .

For developing countries, these data are often not readily available and collecting the information requires significant efforts, such as is currently undertaken in Indonesia, supported by bilateral and institutional investments. Especially the African and American tropics where peatlands indeed occur are of high priority for the inventory (see Chapter 2.1). The default values necessary for estimating the GHG fluxes, are provided by the existing IPCC guidance on peatlands and are further improved in the supplement that will be available in 2013 (see above).

Improving reporting in National Inventories
In their National Inventories, countries have to report emissions and removals from mineral and organic soils separately within the IPCC land categories. From 2005 onwards, Annex I Parties were already obliged to submit emission and removal data from organic soils from back to 1990. The quality of these data varies, however. Some countries use the default Tier 1 method of mineral soils for their forest area on organic soils which may lead to a (severe) underestimation of emissions.

Others reported CO_2 or N_2O emissions from Grassland and Cropland (and in one case even other categories) aggregated (Barthelmes *et al.*, 2009). In several cases countries have reported: "information elsewhere" or - wrongly - "not applicable" (See examples on forest land, cropland and grassland accounting on pp.5, 140, 141, 145, 148, 149, 152,153, 156, 161 of FCCC/WEB/SAI/2011).

As organic soils are a key source of emissions for several countries, reporting should and can be considerably upgraded. Much can be improved already by following the guidance of the IPCC 2006 Guidelines and its supplement once available. Capacity building and basic data gathering with respect to peatland reporting is urgently needed in most developing countries.

The use of proxies
Peatlands do have particularities that make monitoring challenging, including their mix of greenhouse gases and the fact that carbon stock changes cannot easily be used as a proxy for greenhouse gas fluxes. This challenge is however not unique to peatlands and organic soils, but applies also to other activities in the land use and other sectors.

Detailed methodologies for monitoring all major emissions from peat soils in all significant situations either already exist or are rapidly developing. The most obvious thing would be to measure on the project site all GHG fluxes (emissions and removals) that occur before, during, and after the intervention. Indeed, adequate techniques exist to measure these fluxes in detail, but these are generally too complex and too expensive for widespread monitoring. Therefore indirect methods - via so called proxy variables or 'proxies' - are used for assessing the fluxes (Joosten and Couwenberg, 2009). Three methodologies (based on water level, vegetation and subsidence) allow for immediate baseline setting and monitoring, because the proxy data can be immediately mapped and translated into greenhouse gas flux estimates. Accuracy of the estimates can later be improved after improved calibration of the proxies. Several German federal states, for example, have already presented detailed, comprehensive assessments of the actual GHG fluxes from their entire peatland area.

Monitoring of fluxes from tropical peat forests
For tropical countries, all activities and processes related to anthropogenic greenhouse gas fluxes and carbon losses from peat swamp forests (removal of (substantial) tree biomass, increased drainage of peat soils, and peat fires) can easily be monitored. All these fluxes are associated with changes in crown cover of forests on peat soil and/or expansion or alteration (intensification) of drainage structures (canals/ditches) in peatlands.

A simple yet meaningful system of monitoring peatlands at the national level can be based on (existing) maps or atlases, extended with higher resolution data. This information can be combined with:

- wall-to-wall remote sensing of land use and land cover change using high-resolution satellite imagery;
- simple conservative algorithms for assessing the emission effects of land use change; and
- default emission factors in the *2013 Supplement of the IPCC 2006 Guidelines: Wetlands*.

On a district and project level, this system could be refined further, e.g. by using (direct) water level and subsidence measurements to assess emission reductions and carbon removals related to rewetting and reforestation activities. Further refinement of the monitoring system should be encouraged using additional knowledge gained over time.

4.6. Practical solutions for meeting REDD+ safeguard commitments in peatland areas

A number of issues should be considered when dealing with the safeguards defined by the UNFCCC. Safeguards will generally have a high level of country specificity and the following should thus be seen as aspects and examples that need further review within the relevant national or even local context.

Safeguard 1: Policy coherence and consistency with international agreements
In most parts of the world hardly any coherent policies exist for peatlands, reflecting the general lack of knowledge and awareness on peatland values and issues. Instead, national and regional policies and legislation promote or support unsustainable uses of peatland, including drainage, deforestation, drainage dependent agriculture and peat mining, which contribute to the disproportionately high emissions from peatlands worldwide.

Boy running from peatfire, Central Kalimantan, Indonesia
Photo: Alue Dohong

In most countries the idea that natural peatlands are wastelands that should be ameliorated remains embedded in policy and legislation. As a result, the conversion and unsustainable use of peatlands by industry, farmers and local communities (both indigenous groups and immigrants) are generally actively supported with the expectation that this will contribute to economic development and poverty reduction, notwithstanding the serious negative environmental and ensuing socio-economic impacts which are generally not recognized or acknowledged. For instance, the current Indonesian agricultural and forestry policies ignore the long-term impacts of drainage related subsidence that will affect large stretches of coastal areas of Sumatra and Borneo.

REDD+ programs should thus include a focus on review of national, regional and sectoral policies and legislation that impede sustainable peatland management, including restoration and conservation for climate change mitigation.

Safeguard 2: Transparent and effective governance
Similarly, REDD+ programs may offer the opportunity to address some of the current weaknesses and inconsistencies in policy and legislation of various development sectors that impact on the carbon storage and other functions of peatlands.

A useful example is the Presidential decree No 10/11 for a Moratorium on the Issuing of New Licenses and Improvement of Land-Use Planning for Primary Forests and Peatlands in Indonesia, announced in May 2011, which relates to the Memorandum of Understanding (MoU) between Indonesia and Norway for cooperation on REDD+. It provides opportunity to review current land-use and land-use plans and the underlying sectoral development policies and supporting legislation, which over the last decades have led to the most rapid conversion of tropical peat swamp forests worldwide. In the European Union a recent example is the inclusion of peatland specific clauses in the Renewable Energy Directive and the Fuel Quality Directive that take account of the high emissions from biomass produced on drained peatland.

Safeguard 3: Respect for knowledge and rights of indigenous and local communities
Whereas in many countries sustainable traditional uses of peatlands exist (e.g. natural berry and mushroom harvesting, hunting, fisheries and sports fishing, reindeer herding, collection of medicinal plants, use of peatlands for supply of potable water and water for irrigation), there are also examples where traditional use has developed into seriously unsustainable practices. The line between traditional indigenous and modern indigenous may be difficult to draw. It can be questioned, for instance, how traditional peatland drainage for agriculture in Europe is, which in e.g. the Netherlands has rendered one-third of the country to be lying meters under sea level requiring billions of euros for investments in dikes and pump-operated drainage systems. How traditional is the Irish custom that each family is entitled to mine a peat area for producing turf for fuel, a practice that now heavily endangers the last natural bog remnants of Ireland that are officially “protected”? While use of fire played a key role in traditional slash-and-burn agriculture in many tropical forest regions, the expansion of this traditional practice to permanent agriculture of annual crops on peat involves the huge risk of uncontrollable peat fires that result in huge emissions, impact on public health and lead to the loss of natural resources and investments.

Everywhere in the world we can find examples where certain peatland uses that were considered traditional have been abandoned as a result of the ensuing peatland degradation or in relation to economic transitions. To what extent should local and/or traditional rights be acknowledged if this results in serious impact on the valuable ecosystem services of peatlands (including their biodiversity, water supply and carbon storage functions) and will cause the resource base to which the rights apply to be destroyed?

REDD+ programs need to and do offer a new opportunity to review such uses in order to remove or constrain the unsustainable use and strengthen, enhance and/or expand community rights for developing and maintaining sustainable traditional and other sustainable uses such as paludicultures. REDD+ also opens up options for communities to actively participate in peat swamp forest management, rehabilitation and conservation in order to maintain and restore the below and aboveground carbon stores. This may involve reducing emissions by replacing unsustainable traditional land-uses into sustainable peatland use practices as well as carbon sequestration through peatland conservation and paludiculture. Carbon financing may help to trigger such shifts in livelihood. Recently, some 30,000 ha of farmland on peat in North-east Germany were subjected to a land swap moving the farms to mineral soil areas, largely financed with biodiversity conservation subsidies. REDD+ programs should strive to build on and optimize such opportunities to enable equitable sharing of benefits.

Safeguard 4: Full and effective stakeholder participation
Community engagement and provision of community safeguards are essential for land-based carbon projects to enhance effective program implementation and sustainability of results and to reduce business risks. Such engagement is required by the UNFCCC as well as various verification standards and it is included in most Corporate Social Responsibility programs. Moreover, with natural resources becoming a so-called "scarce global property good" local communities and poor in the scramble for these resources tend to end up at the losing end of the rope. REDD+ programs offer the opportunity not only to safeguard local communities for such losses but to make them actually benefit.

In most cases success of REDD+ projects, whether government or private sector driven, will depend on appropriate involvement of local communities and can benefit from indigenous knowledge. The standard of the Climate, Community and Biodiversity Alliance (CCBA) requires proven benefits for both communities and biodiversity and provides as such a suitable starting point to ensure safeguards for vulnerable groups.

With respect to peatlands stakeholder participation is also essential to enable agreement on measures that will restrict or restrain certain uses or even access to areas. In Indonesia, for example, most peatland areas have been bisected by numerous channels, dug for agricultural development (drainage systems) or for illegal logging (channels providing easier access to peat swamp forests and easy way to remove logs). Local community or individual ownership over such channels can be claimed for many reasons, but often channels are appreciated as they do provide easier access to the remaining natural resource base. Effective hydrological rehabilitation will thus require the consent of the official owners as well as the regular users in order to gain their cooperation but also to prevent sabotage. Peatland rehabilitation will require a substantial amount of labor, which can only be provided by local people. Integrating peatland rehabilitation with needs for socio-economic development of local communities can create win-wins for all stakeholders. Blocking of large peatland drainage systems, for instance, may provide opportunity for aquaculture development. Communities in Russian peatlands are known to have prevented peatland drainage to safeguard their berry and mushroom collection areas. Given the right approaches and appropriate consultations with local stakeholders such win-win options can be explored, piloted and upscaled as part of REDD+ programs. Bio-rights, a rights-based approach for combining sustainable economic development with rehabilitation of the natural resource base, environment and biodiversity, offers a mechanism in which soft loans or even interest free micro-credits for sustainable development are provided in exchange of community participation in biodiversity conservation and environment rehabilitation.

Safeguard 5: Biodiversity
Key in REDD+ programs in peatland areas will be the recognition of the need for an ecosystem based approach. The eco-hydrological vulnerability of peatlands requires the securement of the whole functional ecosystem. Whereas it would be preferable to focus on entire catchments, in many countries these may be difficult to secure in the short to medium term as a result of mosaic patterned land ownerships. Especially the rapid conversion over the last decades of tropical peat swamp forest areas in South-east Asia for agriculture development, and the recent land grab by the oil palm and Acacia pulp wood sectors make it difficult to secure entire peat domes. Over 95% of all peatlands in Indonesia and Malaysia have been affected by some level of logging and/or conversion, and it is difficult if not impossible to find any pristine peat swamp forest ecosystem, even in protected areas. In this regard it will be crucial to ensure that under REDD+ priority is given to conserving the remaining peat swamp forests, including forests that have been degraded by selective logging or even more degraded forests that can still have significant value for biodiversity conservation. Within disturbed landscapes REDD+ projects should focus on the largest possible eco-hydrological peatland unit. Highest chances for benefits to biodiversity conservation will be in areas where rehabilitation projects of severely degraded areas are situated adjacent or close to remaining peat swamp forests and other high biodiversity pockets, or where they can provide a corridor function between high conservation value (HCV) areas. In rehabilitation, care should be taken to use indigenous peat swamp forest tree species for reforestation.

Safeguard 6: Actions to address risk of reversal
The main guarantee for prevention of reversals will be the optimal engagement and support of the local communities and other major stakeholder groups. This requires the development of a robust and credible performance base. It necessitates building on full acknowledgement of traditional land ownership and natural resource use rights, in combination with long-term or permanent ecosystem rehabilitation and carbon management plans and regulatory frameworks (such as e.g. long-term carbon concessions). Win-win options will enhance community and other stakeholder support. Private sector involvement in investment in peatland rehabilitation, conservation and sustainable management provides a key option for the necessary long-term financing commitment. This should, however, not reduce pressure on industry and transport sectors to reduce their own emissions. Offsets should be additional to credible GHG emission reduction programs and be limited to compensate only for unavoidable emissions.

Safeguard 7: Actions to reduce displacement of emissions
A major difference of REDD+ projects in peatlands compared to other forests and land areas is that the key element in peatlands is the below ground carbon store. Emissions from clearing a forest primarily involve the removal and oxidation of forest biomass. These emissions can be considered to be more-or-less instantaneous: they stop very soon after clearing stops (and may be promptly reversed by subsequent forest regeneration). In contrast, emissions from peatland drainage continue until the drained area is effectively rewetted (reinstalling water level and revegetation) or the entire peat is depleted - i.e. emissions may continue for decades, or even centuries, after clearing and draining. Drainage of additional areas will add to these ongoing emissions. Whereas reducing emissions from deforestation may be achieved by decreasing the rate of forest conversion, decreasing the rate of peatland conversion will still result in increased emissions. Emissions from already drained peatlands are ongoing and emission from newly drained peatlands will be additional to these. If the rate of conversion is reduced, less emissions are added than were added in previous years, but these emissions will be additional nonetheless. Reducing emissions from peatlands can therefore not be achieved by reducing the rate of peatland conversion but requires active rehabilitation of already drained peatlands. Peatland rehabilitation is the only way to reduce or stop ongoing long-term degradation processes and their related GHG emissions.

If a particular drainage dependent peat land use is stopped there is a chance that this land-use activity will move to another not yet degraded peatland or peat swamp forest, thus causing a displacement of emissions. However, this chance may be relatively small for several reasons:

- There are hardly any non-degraded peat swamp forests left in West-Indonesia and Malaysia. It will be difficult to find any peat dome that is intact (i.e. not been subject to partial logging, conversion, drainage and/or fire). A displaced activity could, however, still enhance emissions in such circumstances, including through deforestation and intensification of drainage.
- For South-east Asia, the region with the highest rate of peat swamp forest conversion, it is anticipated that all peatlands outside of protected areas will under current land conversion policies be deforested and drained within 10 years (Miettinen *et al.* 2012). Displaced land-use activities will thus generally only replace other contenders for the same area.
- In other regions with major peat swamp forest areas and low rates of peat swamp forest degradation it is likely that policy frameworks are already in place that discourage or prevent such new peat swamp forest reclamations. In other cases the REDD+ project should actively work with local stakeholders to identify suitable replacement areas, e.g. degraded and deforested areas on mineral soils that have been in such a state for several years.

Along the coast of Brazil and the countries of the Guyana shield there are extensive peat swamp forests on deep peat, such as along the Rio Preto near Sao Paulo.
Photo: Marcel Silvius

5. Country-wise opportunities

Rene Dommain, Alexandra Barthelmes, Franziska Tanneberger, Aletta Bonn, Clifton Bain & Hans Joosten

The principle of the UN Framework Convention on Climate Change (UNFCCC) that countries have "common but differentiated responsibilities and respective capabilities" explicitly accounts for peatlands. Some countries have hardly any peatlands in productive use whereas others have drained almost their entire peatland resource. Some countries are rich in peatlands, others very poor. Consequently countries' challenges and opportunities with respect to better management and larger mitigation options differ.

In this chapter we illustrate the different responsibilities and opportunities of various countries by example of the following countries and regions:

- Southeast Asia: Indonesia and Malaysia;
- European Union: Poland and United Kingdom;
- Eastern Europe: Belarus, Russian Federation and Ukraine;
- Central Asia: China and Mongolia;
- Africa: Congo basin and Uganda; and
- Amazon Basin: Brazil, Guyana Shield and Peru.

5.1. Southeast Asia: Indonesia and Malaysia

Southeast Asia is by far the world's most important peatland hotspot, with half of the global peatland emissions originating from this region and peat swamp deforestation and drainage being extremely fast.

Tropical peat swamp forests represent a unique ecosystem comprising interdependent biotic and abiotic components (see Box 9). Any change to the natural balance between water, soil and vegetation will result in GHG emissions. The enormous pool of soil carbon in their peats (on average per hectare ten times larger than the carbon stock of tropical forest on mineral soil) makes peat swamp forests in their emission behaviour fundamentally different from "normal" forests (Wibisono *et al.*, 2011).

The distribution and use of peatlands in Southeast Asia are rather well-documented. Large areas of peat swamp forest have been reclaimed for agriculture and plantations or lay temporarily abandoned after deforestation or fire. When drained, deforested or degraded, peat swamp forests release the peat carbon much faster than it has been sequestered (Couwenberg *et al.*, 2010; Dommain *et al.*, 2010 and 2011).

Once disturbed, the remaining peat soils continue to emit and are responsible for enormous greenhouse gas emissions. In Indonesia drained peatlands are responsible for over 60% of its total emissions (DNPI, 2010). The rapid deforestation and drainage of peat swamps for conversion to oil palm and pulp wood plantations has an enormous effect on long-term emission patterns and forms a tremendous threat to biodiversity. Substantial emission reductions are possible, but only if remaining good quality peat swamps are fully protected, vast areas of deeply drained peatland are rewetted and effective fire mitigation measures are implemented.

Rehabilitation of degraded areas that border remaining peat swamp forests or that would provide corridor functions between High Conservation Value (HCV) areas has the highest prospects to improve biodiversity conservation and restoration of ecosystem services such as water retention. Care should be taken to use indigenous peat swamp forest tree species for reforestation.

Box 9: Peat swamp forests: ecology and biodiversity

Peatlands are ecosystems where - under conditions of permanent water saturation - dead and decaying plant material has accumulated to form a thick organic soil layer (peat). Unlike other forest, peat swamp forest is a 'unique ecosystem' with very close interactions between vegetation, peat and water that operate as 'self-regulation' mechanisms and enable these domed organic landscapes to persist under varying climatic conditions for thousands of years (Dommain *et al.*, 2010 and 2011). In natural peat swamp forests, the forest provides the plant material and facilitates the wet conditions for peat formation, carbon sequestration and carbon storage.

Peat swamp forests are the habitat of many endemic plant and animal species. Endemic fauna recorded only in this habitat in Southeast Asia include False Gharial (*Tomistoma schlegelii*), Storm's stork (*Ciconia stormy*), White-winged Wood Duck (*Cairina scutulata*), Hairy-nosed Otter (*Lutra sumatrana*), Black Partridge (*Melanoperdix nigra*), many species of fish, many species of dragonflies, Proboscis monkey (*Nasalis larvatus*), and Flat-headed Cat (*Prionailurus planiceps*). There are also many species of birds found only in peat swamp forests. Until recently many biologists considered the black water of peat swamp forests to be low in biodiversity and productivity. In fact peatlands have simply been poorly studied. In Peninsular Malaysia 10 % of all fish species are found only in peat swamps. Unpublished data show this figure is even higher in Borneo.

Peat swamp forests are also home to many endemic tree species including Ramin (*Gonystylus bancanus*), *Dactylocladus stenostachys*, *Copaifera palustris*, Belangeran (*Shorea belangeran*), Swamp meranti (*Shorea pauciflora*), Jelutung rawa (*Dyera polyphylla*), Pulai rawa (*Alstonia pneumatophora*), Perapat (*Combretocarpus rotundatus*), and Gemor (*Alseodaphne coriacea*). From forty-five Dipterocarps tree species found in peat swamp forest in Sumatra, Kalimantan, Sarawak and Sabah, twenty are classified by IUCN as Critically Endangered, eight as Endangered, three as Vulnerable and one as Least Concern (Paoli *et al.*, 2010).

Ramin (*Gonystylus bancanus*) is one of peat swamp forest endemic species with a high economic value. It was heavily exploited by timber companies and illegal loggings following rocketing international demand. CITES listed this species in Appendix 3 in 2001 and then followed in Indonesia through Ministry Decree No.127/ 2011 on moratorium of Ramin exploitation. In 2004, CITES lifted up the status to Appendix 2. These serious measures have successfully resulted in a significant drop in Ramin exploitation. This example proves that policy intervention can be very effective for conserving and protecting selected species.

Indonesia

Peatland distribution
Indonesia is the country with the largest tropical peatland area. Of the globally 440,000 km^2 tropical peatland (Page *et al.*, 2011) 210,000 km^2 are located in Indonesia (Wahyunto *et al.*, 2003, 2004 and 2006). The peatland areas are found in Indonesian Papua (79,755 km^2), Sumatra (72,043 km^2) and Kalimantan (57,692 km^2; Wahyunto *et al.*, 2003, 2004 and 2006).

Peatland use and degradation
Originally all the lowland peatlands of western Indonesia were forested. However, intensive land-use, particularly over the last twenty years, has massively reduced the cover of peat swamp forests, particularly in Sumatra and Kalimantan (Table 4, Miettinen *et al.*, 2011 and 2012a). Of the original over 210,000 km^2 peat swamp forests in Indonesia only 100,000 km^2 remained by 2010 (Table 4).
Most peat swamp forest in Indonesia has been and still is destroyed for small-holder agriculture under the transmigration programme, for industrial plantations of African oil palm (*Elaeis guineensis*) and Acacia pulpwood, by overexploitation of the timber resources through concession based and illegal

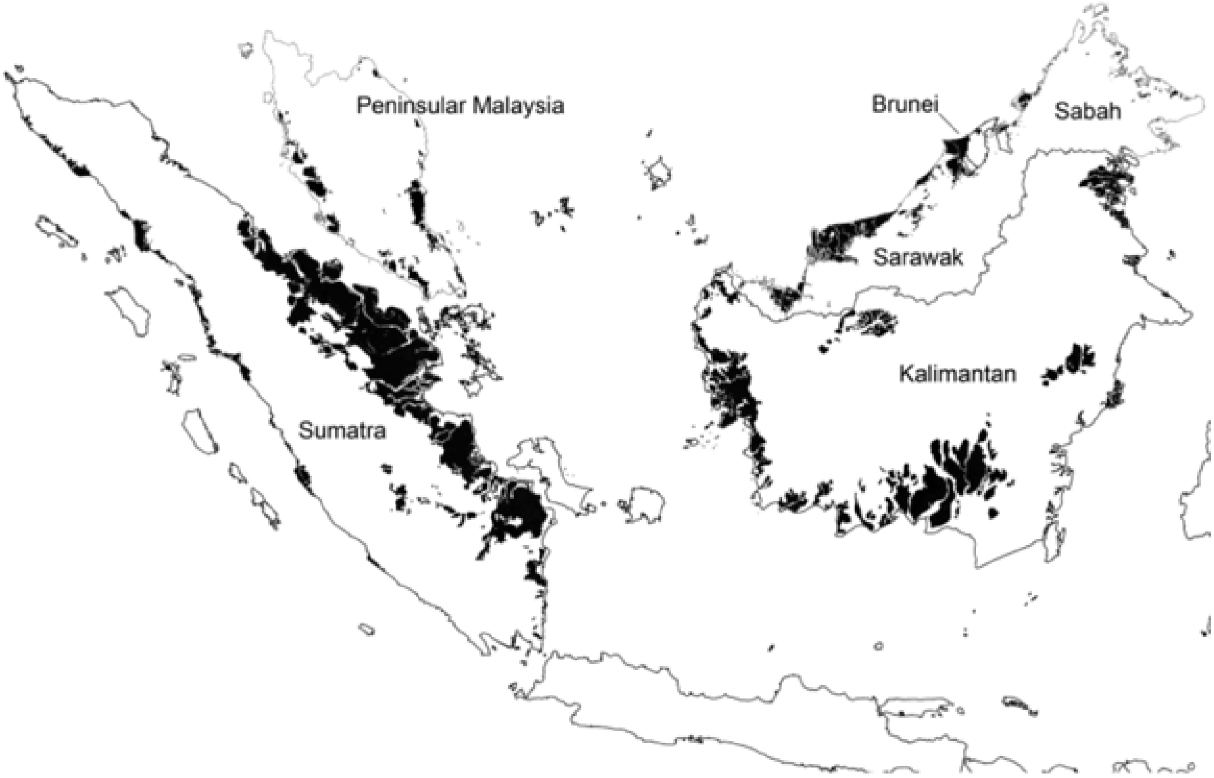


Figure 3. Extent of peatland in Peninsular Malaysia, Sumatra, and Borneo (from Posa *et al.*, 2011)..

logging and by destructive fires. Western Indonesia (i.e. Kalimantan and Sumatra) will lose all of its peat swamp forests by 2030 if current deforestation rates of 3.4% yr^{-1} are not reduced (Miettinen *et al.*, 2012a). The recent land cover distribution for Kalimantan and Sumatra has been quantified by Miettinen and Liew (2010) as shown in Table 4. Similar data for Papua are not available.

In 2007 already 31% or ca. 41,000 km^2 of the peatlands of Sumatra and Kalimantan were under agricultural use of either small-holder farming or industrial plantations (oil palm or pulp wood). The extent of the remaining, largely degraded forested peatlands amounted to 53,500 km^2 or 41 % (Table 5). The extent of pristine peat swamp forest in western Indonesia has become negligible.

The expansion of oil palm and pulp wood plantations continues at rapid rates. By 2010 industrial plantations in Sumatra and Kalimantan covered ~23,000 km^2 and under a business as usual plantation expansion scenario further peatland conversion would result in an almost doubling of the plantation area by 2020 (Miettinen *et al.*, 2012b). In fact, Indonesia has allocated large peatland areas for further agricultural conversion (MoF, 2010).

Table 4. Peat swamp forest (PSF) cover estimates for Indonesia.

	Original[1]	1990		2000		2010	
	PSF (km^2)	PSF (km^2)	(%)	PSF (km^2)	(%)	PSF (km^2)	(%)
Sumatra[2]	72,043	49,216	68	30,785	43	18,069	25
Kalimantan[2]	57,692	38,570	67	28,692	50	24,035	42
Papua[3]	79,754	n.a.	n.a.	63,360	79	59,700	75
Indonesia	209,490			122,837	59	101,804	49

[1] *Original PSF cover assumed to be equal to peatland area of Wahyunto et al. (2003, 2004, 2006).*
[2] *Data for 1990-2010 taken from Miettinen et al. (2012a).*
[3] *Data for 2000-2010 taken from Miettinen et al. (2011).*

Table 5. Land cover distribution on peatland in western Indonesia (Sumatra, Kalimantan) in 2007.

	Sumatra		Kalimantan		Western Indonesia	
Land cover type*	Land cover area (km^2)	Land cover area (%)	Land cover area (km^2)	Land cover area (%)	Land cover area (km^2)	Land cover area (%)
Water	444	0.6	113	0.2	557	0.4
Seasonal water	514	0.7	2,522	4.4	3,036	2.3
Pristine PSF	3,353	4.6	1,217	2.1	4,570	3.6
Slightly degraded PSF	4,357	6	5,734	9.9	10,091	7.7
Moderately degraded PSF	13,610	18.9	21,343	37	34,952	26.6
Heavily degraded PSF	2,535	3.5	1,355	2.3	3,890	3
Tall shrub/sec. forest	5,070	7	5,747	9.9	10,817	8.3
Ferns/low shrub	7,605	10.5	8,206	14.2	15,811	12.1
Small-holder agriculture	17,360	24.1	6,888	11.9	24,248	18.9
Industrial plantations	15,280	21.2	1,242	2.2	16,523	13.1
Built-up area	70	0.1	25	0	95	0.1
Cleared/burnt area	1,869	2.6	3,230	5.7	5,169	3.9
Total peatland	72,079	100	57,691	100	129,759	100

**Land cover distribution based on Miettinen & Liew (2010), but all values were corrected to 100% peatland area (i.e. corrected for the unmapped area) by applying the same land cover proportions as in the mapped area (= 85.6% for Sumatra, 79.7% for Kalimantan, see Miettinen & Liew 2010).*

Carbon stock and greenhouse gas emissions

The peatlands of Sumatra and Kalimantan largely developed over the last 11,000 years (Dommain *et al.*, 2011). The widely distributed coastal peat domes have Holocene mean carbon accumulation rate of 77 g C m^{-2} yr^{-1}, whereas the inland peat domes of Central Kalimantan accumulated on average 31.3 g C m^{-2} yr^{-1} over the Holocene. Estimates of Indonesia's peatland carbon reservoir differ markedly. Wahyunto *et al.*, (2003, 2004, 2006) report 37.18 Gtonnes C, Jaenicke *et al.* (2008) give a higher estimate of 55±10 Gtonnes based on corrected peat extent and volume while Page *et al.* (2011) provide an estimate of 57.37 Gtonnes C.

Table 6 shows that the peatlands of Kalimantan and Sumatra emitted about 446 Mtonnes CO_2 in 2007. The vast majority of these emissions comes from agriculturally used land due to dense and deep drainage. The negative carbon balance of over 60% of the area shows that Indonesian peatlands have switched from an effective carbon sink to a substantial carbon source. Including fire emissions even doubles the carbon losses from peat degradation (van der Werf *et al.*, 2008).

Opportunities for emissions reductions and enhancement of other ecosystem services

As approximately 95% of Indonesia's peatlands are already degraded, restoration should be a priority action together with the conservation of remaining reasonably natural peatlands in the REDD+ Strategy. Substantial emission reductions are only possible if the vast areas of deeply drained peatland are rewetted and effective fire mitigation measures are implemented. Continuous expansion of oil palm and pulp plantations would further increase carbon losses substantially.

Table 6. Land cover distribution and related annual CO_2 emissions in 2007 from drainage related peat oxidation in western Indonesia (Sumatra and Kalimantan) (i.e. fire related emissions excluded).

Land cover type*	Land cover area (km^2)	Land cover area (%)	Fraction drained area (%)	Drained area (km^2)	Mean annual drainage depth (cm)	Mean annual CO_2 emission (tonnes/ha)	Total annual C emissions (tonnes)	Total annual CO_2 emissions (tonnes)	Emission contribution (%)
Water	557	0.4	0	0	0	0	0	0	0
Seasonal water	3,036	2.3	0	0	0	0	0	0	0
Pristine PSF	4,570	3.5	0	0	0	-2.56	-4,300,753	-1,172,933	0
Slightly degraded PSF	10,091	7.8	50	5,046	35	35	17,660,089	4,816,388	4
Moderately degraded PSF	34,952	26.9	50	17,476	35	35	61,166,608	16,681,802	13.5
Heavily degraded PSF	3,890	3.0	50	1,945	35	35	6,807,724	1,856,652	1.5
Tall shrub/sec. forest	10,817	8.3	50	5,408	35	35	18,929,125	5,162,489	4
Ferns/low shrub	15,810	12.2	50	7,905	35	35	27,669,096	7,546,117	6
Small-holder agriculture	24,248	18.7	100	24,248	80	80	193,985,155	52,905,042	43
Industrial plantations	16,523	12.7	100	16,523	70	70	115,657,723	31,543,015	26
Built-up area**	95	0.1	-	-	-	0	0	0	0
Cleared/burnt area	5,169	4.0	50	2,585	35	35	9,045,808	2,467,039	2
Total	129,759								
Sum drained area (ha) (%)				81,136 63					
Sum annual emissions (t)							**446,620,576**	**121,805,612**	

**Land cover distribution based on Miettinen and Liew (2010). ** Build-up area assumed to be completely sealed. CO_2 emissions based on a linear relationship with drainage depth: 10 t CO_2 ha^{-1} yr^{-1} for each 10 cm of drainage (cf. Couwenberg et al., 2010, Hooijer et al., 2012). Peat carbon sequestration in pristine PSF is assumed to be 0.7 t C ha^{-1} yr^{-1} (Dommain et al., 2011).*

Malaysia

Peatland distribution

Among the Southeast Asian countries Malaysia has the second largest peatland area. Mutalib *et al.* (1992) estimate the extent of Malaysian peatlands at 25,889 km^2. The state of Sarawak has the largest share of the country's peatland area (Table 7).

Table 7. Peat swamp forest cover estimates for Malaysia.

	Original[1]	1990[2)]		2000[2)]		2010[2)]	
	PSF (km^2)	PSF (km^2)	%	PSF (km^2)	%	PSF (km^2)	%
Peninsular Malaysia[2]	8,453	3,797	45	2,808	33	2,299	27
Sarawak[2]	16,576	9,656	58	7,180	43	3,075	19
Whole country[2]	25,889	14,482	56	10,484	40	5,726	22

[1] Original PSF cover assumed to be equal to peatland area of Mutalib et al. (1992).
[2] Data for 1990-2010 taken from Miettinen et al. (2012a).

Table 8. Extent of industrial plantations on peat in Malaysia in 2010.

	Original[1]	Oil palm plantation[2)]		Other/unknown plantation[2)]		Total plantation[2)]	
	km²	km²	%	km²	%	km²	%
Peninsular Malaysia	8,453	2,380	28	230	3	2,620	31
Sabah	860	500	58	20	2	520	60
Sarawak	16,576	4,940	30	310	2	5,250	32
Total	25,889	7,820	30	560	2	8,390	32

[1] *Original PSF cover assumed to be equal to peatland area of Mutalib et al. (1992).*
[2] *Data for 2010 taken from Miettinen et al. (2012b).*

The peatlands of Malaysia are dominantly dome-shaped and rainwater-fed, similar to European raised bogs. The peat domes are all of Holocene origin, typically younger than 7000 years BP (Dommain *et al.*, 2011). On Pensinsular Malaysia some freshwater swamps exist in the interior such as Tasek Bera (Wüst and Bustin, 2004).

Peatland use and degradation
It can be assumed that most peatlands of Malaysia were naturally forested; this assumption is certainly true for the dominating peat domes. Peat swamp deforestation in Malaysia is shown in Table 7. Already in 1990 large areas of peatland were deforested, most notably on Peninsular Malaysia where cultivation with pine apple, oil palm and other crops on plantation scales started in the 1970s. From 1990 to 2000 Peninsular Malaysia and Sarawak experienced similar peat swamp deforestation rates (~3% yr^{-1}), but since 2000 deforestation in Sarawak (8.1% yr^{-1}) has accelerated massively while it slowed down on Peninsular Malaysia (2% yr^{-1}) (Miettinen *et al.*, 2012a). A little more than half a million hectare peat swamp forest remains in Malaysia - this is proportionally clearly less peat swamp forest than Indonesia has left.

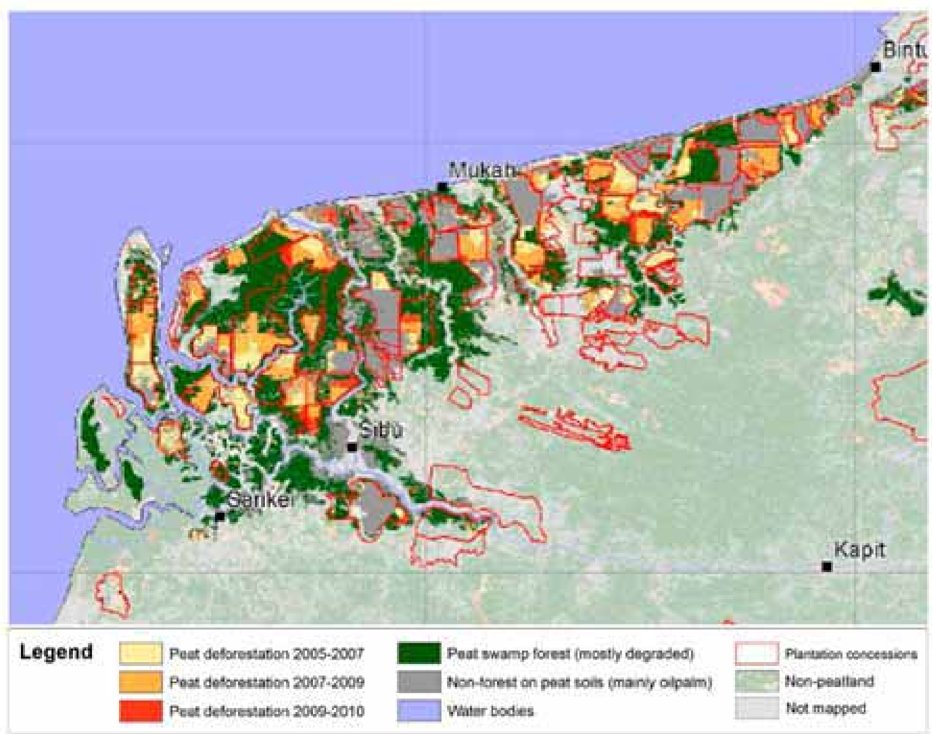


Figure 4: Distribution and status of peat swamp forest in Sibu Division, Sarawak (Malaysia) (after SarVision, 2011).

The rapid deforestation of remaining peat swamp forest can largely be attributed to the expansion of oil palm plantations (SarVision, 2011). Today 30% (almost 8,000 km^2) of Malaysia's peatlands are under oil plantations. The bulk of Malaysia's oil palm plantations on peat occur in Sarawak where in 2010 almost half a million hectare were cultivated (Table 8). SarVision (2011) reports that even 41% of Sarawak's peatlands are converted to oil palm. Expansion of oil palm does not stop for deep peat areas or rare peat swamp forest types (Wetlands International, 2010). So far, there have been no pulp plantations planted in Malaysia.

Carbon stock and greenhouse gas emissions
Page *et al.* (2011) estimate the peat carbon stock of Malaysia at 9.1 Gtonnes based on the areal extent given in Mutalib *et al.* (1992). Multiplying the extent of industrial plantations with the typical plantation emission factor of 70 tonnes CO_2 ha^{-1} yr^{-1} (Hooijer *et al.*, 2012) results in an annual CO_2 loss of 58.73 Mtonnes from Malaysian peatland plantations in 2010. This carbon loss is very likely to grow since most remaining peat swamp forest outside conservation areas is already allocated to oil palm concessions and deforestation and drainage will therefore not stop (Figure 4, SarVision, 2011). A change in this land-use policy is not in sight.

Opportunities for emissions reductions and enhancement of other ecosystem services
Similarly to Indonesia, restoration should be a priority action in the REDD+ Strategy. Substantial emission reductions are only possible if vast areas of deeply drained peatland are rewetted. Continuous expansion of oil palm and pulp plantations would further increase carbon losses substantially. Priority for conservation and rewetting have the peat swamps along the Brunei border in Sarawak, cross-boundary drainage effects threaten the pristine peatlands of Brunei, which belong to the last ones of entire Borneo.

5.2. European Union: Poland and United Kingdom

Its long history, high population pressure, and climatic suitability for agriculture and forestry have made Europe the continent with the largest proportion of drained peatlands worldwide. Consequently the European Union is - after Indonesia and before the Russian Federation- the world's second largest peatland emission hotspot (Joosten, 2009 and 2012).

In the EU27 cropland on organic soil is responsible for 77% of the CO_2 emissions from all cropland and grazing land on organic soil for 79% of the emissions from all grazing land (Table 9). The hotspot character of organic soils in land use is thus evident, as organic soils occupy only a few per cent of the total agricultural area. Emissions from cropland are the most substantial ones, because cropland requires deeper water levels than grazing land. Reported emissions from forest are generally low because the emission factors are low, but also because several countries - wrongly - claim that carbon stocks under existing forests on organic soils are stable (Barthelmes *et al.*, 2009).

The awareness of the unsustainable use of peatlands and its consequences for GHG emissions is increasing in the European Union. Recently the European Commission (EC) has proposed its Member States obligatory accounting for emissions and removals from cropland management (CM) and grazing land management (GM), which together with the already obligatory forest management (FM) cause 90% of the emissions from organic soils in the European Union (EU). In addition, Member States can opt to account for emissions and removals from "wetland drainage and rewetting" (WDR).

The proposal also excluded LULUCF activities from the 2008 climate and energy package that defines the EU's climate policy for the period up to 2020. The EC acknowledged though that LULUCF activities have a substantial impact on overall emission across the European Union. As the sector has is a substantial potential for emission reductions, LULUCF should be formally included in commitments once the EU decides to increase its ambition level. The report indicates that mitigations actions should already start and national action plans could be prepared to provide a strategy and forecast for LULUCF as an intermediate step towards the sector's full inclusion with current policies. See further information and policy recommendations in Chapter 3.

Table 9. Data on organic soils in national GHG inventory year 2010 (EU 27) (Blujdea *et al.*, 2012).

IPCC land subcategory	Area (km^2)	Implied emission factor (tonne C ha^{-1} yr^{-1})[1)]	Net annual C stock change (Mtonnes C)	Share in annual fluxes (%) on each land sub-category
5A1 - Forestland remaining FL	126,230	-0.40	-5.01	5%
5A2 - Land converted to FL	4,110	-0.64	-0.26	2%
5B1 - Cropland remaining CL	19,060	-5.22	-9.95	69%
5B2 - Land converted to CL	980	-7.45	-0.73	8%
5C1-Grassland converted to GL	17,470	-2.61	-4.55	78%
5C2 - Land converted to GL	610	-2.64	-0.160	1%
Total	168,450		-20.67	

[1] *For CO_2 multiply times 3.67..*

Poland

Peatland distribution

Poland (312,684 km²) has a total area of peatland of 12,547.58 km². The northern zone on the Baltic coast comprises 74.2% of all Polish peatlands (8,268 km²), the midland zone 24.3% (4,247 km²), and the southern zone along the Sudety and Karpaty mountains 1.5% (268 km²) (Ilnicki *et al.*, 2002). Fens occupy 92.35%, transitional bogs 3.3% and raised bogs 4.35% of the total peatland area (Ilnicki *et al.*, 2002). In 77% of the 49,500 peatland sites the peat layer does not exceed 2 m depth (Ilnicki and Zurek, 1996).

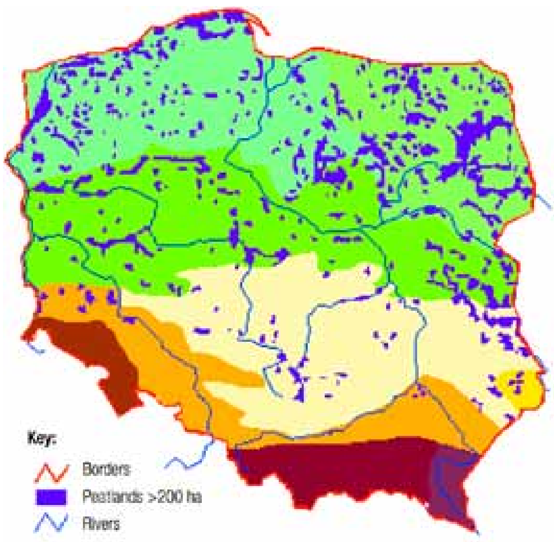


Figure 5: Biogeographical regions in Poland and distribution of peatlands larger than 2 km²
(from Bragg and Lindsay, 2003).

Figure 6: The globally threatened Aquatic Warbler is a flagship species for fen mires and has triggered major peatland conservation, rewetting and sustainable use projects across Europe.
Photo: Zymantas Morkvenas

Peatland use and degradation

Most Polish peatlands are used as hay meadows and pastures (70%). Forests cover 12% of the peatland area, peat extraction has occurred on 4% and arable land occupies 0.5%. 84% of all Polish peatlands are degraded, and the surviving mire area where peat formation still occurs is 201,938 ha (0.6% of the country area; Kotowski and Piorkowski, 2003).

Carbon stock and greenhouse gas emissions

The estimated peat carbon stock of Poland is 875 Mtonnes C. With respect to peatland emissions, Poland is the 10^{th} most important country in the world (23.5 Mtonnes CO_2 $year^{-1}$) (Joosten, 2009).

Box 10: "Wet agriculture" for conserving a little brown bird

The vast fen peatlands of the Biebrza National Park (Northeast-Poland) are a stronghold of biodiversity, holding almost 20% of the world population of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*) (Figure 6). After traditional hand-scything had ceased around 1970, successional overgrowth became the main threat to this habitat. A project funded by EU LIFE and run by OTOP BirdLife Poland recently catalyzed the implementation of landscape-wide restoration and sustainable management. Since 2007 machinery capable of mowing large areas of delicate peatlands was tested and since 2009 adapted mountain piste-bashers, colloquially called 'ratrak' in Poland, are used (Lachmann *et al.*, 2010). Currently, the Biebrza National Park makes some 10,000 ha of public land available under lease agreements to be managed in this way. The harvested biomass is planned to be mainly used for producing fuel pellets. A targeted Aquatic Warbler agri-environment package provides a financial incentive for local farmers and enterprises. A follow-up EU LIFE project is currently upgrading and upscaling fen management with 'ratraks' and utilization of fen biomass in Eastern Poland.

Opportunities for emissions reductions and enhancement of other ecosystem services
Peatland rewetting has been largely restricted to small-scale activities (mainly on bogs) in Western Poland, and there is little large-scale rewetting experience. But the mitigation potential of Polish peatlands is vast: although most Polish peatlands have been drained to some degree, very few areas have been transformed into ploughed arable fields, since national management principles aim to minimize losses of organic matter through mineralization. The preferred land-use for peatlands is permanent grassland, with the result that Poland has a great number of meadow communities on (mainly decomposed) peat soils, many of which have high biodiversity value. Maintenance of these systems with high water tables which substantially reduce greenhouse gas emissions and continued 'wet' land use offers a stunning opportunity to conserve traditional human landscapes as well as rare species and ecosystems.

Since 2000, Poland has gained considerable experience in developing integrated management schemes that combine peatland conservation with economically sound agricultural and hydrological management on near-natural peatlands. A major stimulus has been caused by projects on multi-functional use of peatlands and targeted bird conservation activities (see Box 10). Since 2004, agriculture on wet fens benefits substantially from EU agri-environmental programmes with special packages for the management of fens, bogs and wet meadows.

Opportunities for emissions reductions and enhancement of other ecosystem services
A peatland strategy to mitigate climate change and enhance biodiversity should comprise
- Restoration of the water regimes of drained peatlands and shift to 'wet' forms of agriculture and forestry (paludicultures).
- Securing effective protection of near-natural peatlands, including the prohibition of peat extraction.
- Development and implementation of wise land-use scenarios for major peatland areas, taking advantage of EU agricultural payments and other sources of EU funding.
- Lobbying for CAP incentives for peatland rewetting and paludicultures and against "perverse" incentives (e.g. growing maize on drained peatlands for biogas).
- Updating of the national mire inventory to sharpen the identification of target areas.

These steps are also needed in other EU countries with a large proportion of drained peatlands which have similar problems and challenges, e.g. Germany, Lithuania, Latvia, and Estonia.

United Kingdom

Peatland distribution
In the United Kingdom (UK), deep peaty or organic soils cover around 27,000 km^2 or 11% of the total UK area and shallow peaty soils another 47 000 km^2, indicating where peatland habitats existed in the past - in total a third of all UK soils (Figure 7).

There are three main types of peatland in the UK: blanket bogs, raised bogs and fens, all protected under international and national wildlife law. The UK Biodiversity Action Plan lists 23 000 km^2 of peatland habitat covering about 9.5% of the UK, with the majority in Scotland. Blanket and raised bogs make up 95% of all UK peatland habitat.

Peatland use and degradation
The state of UK peatlands and organic soils has recently been compiled in the JNCC report (2011) and the IUCN UK Commission of Inquiry on Peatlands (Bain *et al.*, 2011).
Over 80% of UK peatlands are in a degraded state due mainly to past, drainage, fire and grazing. The majority of UK peatlands are not peat forming: 16% are severely eroded, 10% have been afforested, 11% are affected by past peat cutting and 40% have been modified or destroyed by conversion to agriculture (Littlewood *et al.*, 2010). The majority of degraded peatland is blanket bog with drainage for grazing as the main past driver, while drainage for cropland was more restricted to lowland peat soils. Forestry planting occurred on around 2000 km^2 deep peat, mainly in Scotland.

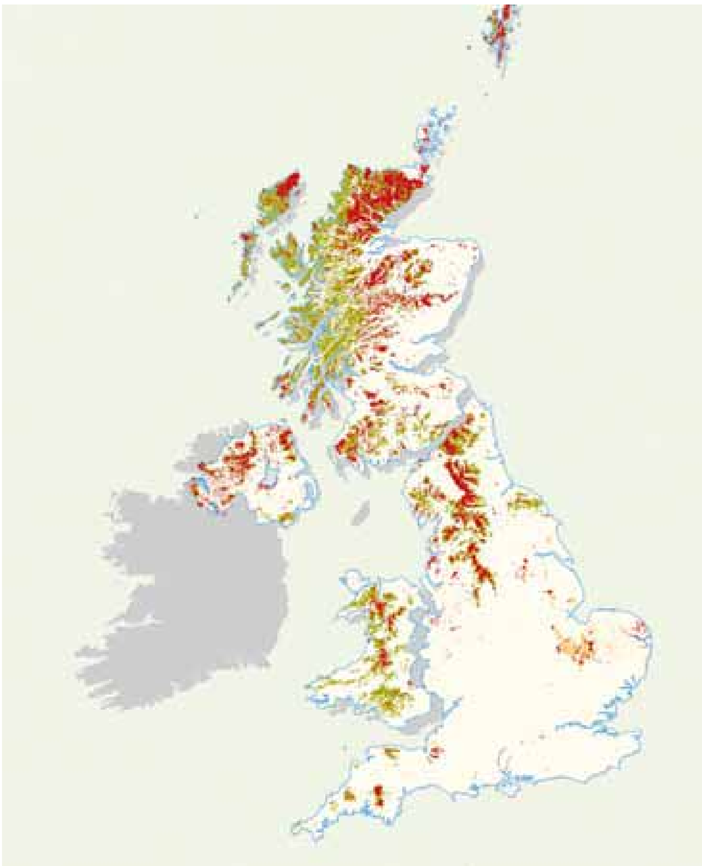


Figure 7. Peat and peaty soils of the United Kingdom (map reproduced from JNCC, 2011). Deep peat soils (dark brown), shallow peaty soils (green), wasted deep peat soils (light brown). Peat in South-East England is largely fen peat. Reproduction by permission of OS on behalf of HMSO@ Crown copyright and database Right 2010, MLURI 100019294, AFBI 1:50000 soil digital Data, National soil Maps @ Cranfield University, BGS 1:50000 digital data (license 2006/072)

Within the most important, nationally and internationally protected sites (SSSIs/ SACs / SPAs), only around half (58%) of the blanket bog habitat is considered to be in favourable condition (JNCC, 2011), with 15% of the remainder considered to be recovering as a result of restoration work. For designated lowland raised bog sites, only around 20% is considered to be in favourable condition, while 35% of the remainder is under restoration management.

Table 10. Extent of organic-rich soils and bogs and fen in the UK (from IUCN UK PP 2011, adapted with kind permission from JNCC 2011)

	Soil map data		UK Biodiversity Action Plan data	
	Shallow peaty or organo-mineral soil [km²]	Deep peaty or organic soil [km²]	Bogs [km²]	Fens[1] [km²]
England	7,386	6,799	2,727	80
Wales	3,592	706	718	62
Northern Ireland	1,417	2,064	1,609	30
Scotland	34,612	17,269	17,720	86
Total area	47,007	26,838	22,775	258
UK area cover	19.30%	11.00%	9.35%	0.11%

[1] current best estimates of fen habitat, but actual area may be much larger (Peter Jones, CCW, pers. comm.).

Carbon stock and GHG emissions
The CEH Carbon catchment programme and the recent Defra project SP1210 "Lowland peatland systems in England and Wales - evaluating GHG fluxes and carbon balances" provide long-term data on GHG fluxes from peatlands (see Billett *et al.*, 2010; Worrall *et al.*, 2010 and 2011).

Within the UK, peatlands represent the single most important terrestrial carbon store with deep peat bogs containing over 3,200 Mtonnes of carbon (Worrall *et al.*, 2010b), approximately twenty times that of UK forests. Semi-natural and natural bog peatlands may remove approximately 30-70 tonnes of carbon per km^2 per year from the atmosphere (Billett *et al.*, 2010; Worrall *et al.*, 2010). Healthy peat bogs have a net long-term cooling effect on the climate.

Damaged UK peatlands are already releasing almost 3.7 Mtonnes CO_2 eq. each year (Worrall *et al.*, 2011) - equivalent to the average emissions of around 660,000 UK households. These emissions are likely to increase with further peatland deterioration as the climate changes.

Opportunities for emissions reductions and enhancement of other ecosystem services
Net emissions can be reduced through restoration action, and restored peatlands are likely to be more resilient to additional stresses from climate change impacts. Deep peaty soils in the UK cover 27,000 million km^2 of which 18,000 million km^2 are available for restoration.

Securing 10,000 km^2 of peatland under rewetting and restoration management would meet the UK Biodiversity Action Plan targets for blanket and raised bog restoration (8,450 km^2). Taking a conservative estimate, this could mean savings of 2.5 Mtonnes CO_2-eq. per year (assuming 2.5 tonnes CO_2-eq savings per ha per year). This equates to 1% of the annual greenhouse gas reductions which need to be made from now to reach the UK climate change target for 2027.

Real opportunities exist to repair peatlands by blocking drains, reducing grazing and burning and removing forestry plantations. Rewetting and restoring blanket and raised bog are the low hanging fruit as there is consensus from land managers, little conflict with food security concerns, and most often only low-cost, low-tech management required (£6 to £13/tonne CO_2-eq for drain blocking, see Moxey, 2011). There is also potential for reverting cropland on fens back to wetland but this concerns only a small proportion of UK peatland.

Funding to pay for restoration and ongoing maintenance of peatlands is key, as most of the peatland area in the UK is privately owned. The EU CAP can be a major source of current funds for peatland restoration to support sustainable land-use. An important goal is to ensure that the multiple benefits of peatlands for biodiversity, water and carbon are recognized under EU CAP and that appropriate payments are available to reflect this. The EU LIFE programme also provides significant restoration funds and further opportunities exist to demonstrate through restoring important peatland sites how nature can provide wider, social and economic benefits.

More coordinated baseline studies and long term monitoring of peatlands in relation to vegetation changes and corresponding ecosystem services (GHG, water quality, flooding) are required to support further financial investment. Sharing good practice on peatland management and scientific information across peatland countries is an important objective.

The IUCN UK NC Peatland Programme and partners are working in collaboration with Defra (Department of Environment) to explore options for drawing in carbon funds through voluntary carbon markets, corporate social responsibility schemes and payments for ecosystem services. The Programme is also planning an information "gateway" on peatlands in the UK linking with international initiatives such as the International Mire Conservation Group and Wetlands International.

The experience of the UK with blanket bog conservation, restoration and management may benefit other countries where this peatland type occurs, including Ireland, Norway, New Zealand, Tasmania, Atlantic Canada, Pacific Northwest, Southern Chile, Argentina and Falklands, and Spain.

5.3. Eastern Europe: Belarus, Russian Federation and Ukraine

Drained peatland soils are subject to inherent degradation, which continuously lowers their economic value. The socio-economic changes in Eastern Europe since 1990 coincided with deteriorating peat soil conditions leading to large-scale abandonment. The huge peatland fires of 2010 brought the drained and abandoned peatlands in Russia under the attention of the world and showed that peat fires are not limited to Southeast Asia. If not rewetted, peatlands continue to go up in air by incessant microbial peat oxidation and - in case of abandonment - also by periodic uncontrolled peat fires. In all three countries presented here - Belarus, Russian Federation (European part) and Ukraine - large-scale peatland rewetting programmes have in recent years started, with different backgrounds and different aims.

Belarus

Peatland distribution

Belarus (207,600 km^2), located in the geographic centre of Europe, is one of Europe's key peatland countries. Before drainage and peat extraction started, peatlands covered 29,390 km^2 which equals 14.2% of the total land area (Bambalov *et al.*, 1992). Despite its small size, the country comprises a wide variety of peatland types depending on climate, bedrock, relief, and hydrological network. Due to large variation in these factors, amount and types of peatlands are not equally distributed within larus. Five peatland districts and three peatland regions have been described (Figure 8, Pidoplichko, 1961; Tanovitskiy, 1980; Bambalov, 2005).

Peatland use and degradation

Between 1960 and 1990 half of the country's peatlands were drained, largely to make way for agriculture (Tanovitskaya and Bambalov, 2009; cf. Figure 9). As a result, the overall area of drained peatland in Belarus is 15 050 km^2 of which 10,852 km^2 (72%) are drained for agriculture, 3,830 km^2 (26%) for forestry, and 368 km^2 (2%) are currently used for industrial peat extraction. Today vast areas of the once cultivated land sit idle, while the drainage system, in most cases, has never been reversed. With ongoing drainage, annual GHG emissions continue, further propelled by peat fires that occur frequently.

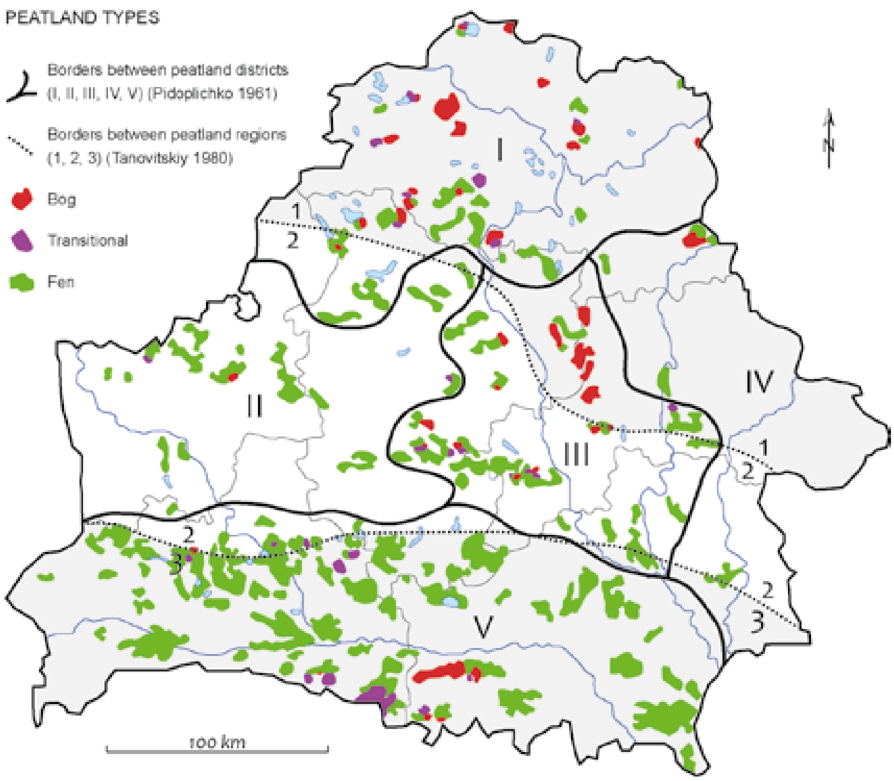


Figure 8: Distribution of peatlands in Belarus (modified after Bambalov and Rakovich, 2005; map: Stephan Busse).

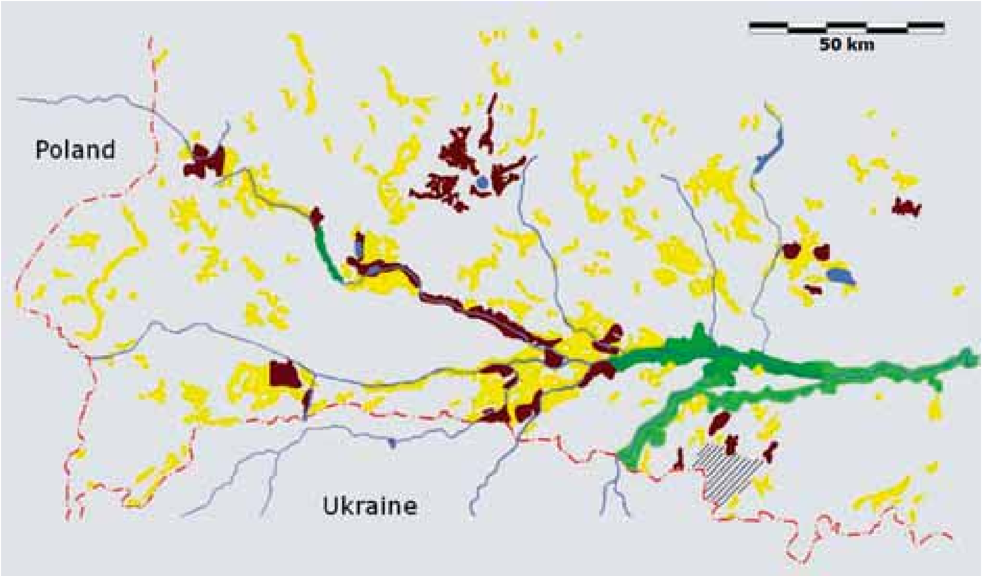


Figure 9: Map of fen mires in South-Western Belarus existing in 1977 (yellow) and remaining in 1995 (brown). Dark green indicates the natural Pripyat river floodplain and light green the Pripyat river floodplain used for low-intensity farming (from Kozulin and Flade, 1999).

Carbon stock and greenhouse gas emissions

The estimated peat carbon stock in 2008 of Belarus is 1,305 Mtonnes C. With respect to peatland emissions, Belarus is with 41 Mtonnes CO_2 year^{-1} the eigth most important country in the world, in terms of emissions per unit land area, even the world's number three after Indonesia and Estonia (Joosten, 2011).

Opportunities for emissions reductions and enhancement of other ecosystem services

Sponsored by UNDP and GEF (2006-2010) as well as the German Ministry of Environment (BMU) (2008-2011), approximately 360 km^2 of peatland have been rewetted over the last years (see Box 6).
Biodiversity benefits of rewetting have been assessed by the UNDP/GEF project (2006-2010) by monitoring before and after rewetting. Generally, wetland plant communities on project sites increased in area by 58 to 96% and the proportion of wetland bird species of the sites increased by 19 to 48%. For example, at the cutover fen Barcianicha after rewetting typical 'forest' amphibians declined from 54% to 31% and previously unrecorded species typical of peatlands were found (e.g. Moor Frogs Rana arvalis and Common Lizards *Zootoca vivipara*). The effects of rewetting on bird as well as on amphibian and reptile communities were rather pronounced even one year after rewetting. Generally, the rate of vegetation (and thus habitat) change varies with target habitat type, pre-exploitation habitat type, and previous land uses. Much quicker success has after extraction been reported from block cut bogs than from milled bogs. Fen vegetation re-develops towards target vegetation more easily after drainage reversal, with the greatest success achieved by rewetting slowly (as opposed to rapid, permanent inundation of sites). Transitional stages (e.g. shallow water bodies) can provide valuable habitats for waterfowl, but these are transient and are not typical habitats for the target communities of most conservation concern (Tanneberger, 2011).

Following Poland's recent advances in establishing wet agriculture on near-natural fens with benefits for biodiversity conservation (see Box 10), also in Belarus paludiculture initiatives have started. At Sporava, another key Aquatic Warbler breeding site holding circa 5% of the global population, overgrowing of habitat is a key threat. Vegetation management with conventional agricultural equipment started in 2006 but appeared to be too weather and water level dependent. A feasibility study (2009) and follow-up business plan (2010) showed that the most cost-effective way of using biomass from Sporava is the production of fuel briquettes. A 'ratrak' funded by the BMU project (see information on Poland above) was delivered to Belarus in autumn 2011 and will facilitate mowing of 500 ha annually. The biomass briquettes produced will be sold as a substitute for peat briquettes (widespread in use in rural areas of Belarus) and will hopefully cover the costs of vegetation management. A follow-up EU AID-funded project has initiated cooperation with a peat briquette factory for substituting peat by sustainably harvested peatland biomass. It aims at upscaling this new type of land use to rewetted peatlands, thus demonstrating feasibility and opening incentives for rewetting and 'wet' land use.

Russian Federation (European part)

Peatland distribution

The European part of Russian Federation (3.477 million km^2) comprises some 200,000 km^2 of peatland (Markov and Khoroshev, 1986; Vompersky *et al.*, 1996, 2005; table 11), although other sources on the basis of other inventory methods arrive at double that area (Novikov and Usova, 2000). Most peatlands are located in Russia's boreal zone, where, in some regions, mires cover over 50% of the land surface (Minayeva *et al.*, 2009; Figure 10).

Table 11. Peat-covered wetlands (in km^2) in European Russia (Vompersky *et al.*, 1996).

Peat thickness				
> 0 cm	>0 - 30 cm	≥ 30 cm	> 0.5 m	
			Total	Industrial deposits
588,000	375,000	213,000	198,000	105,100

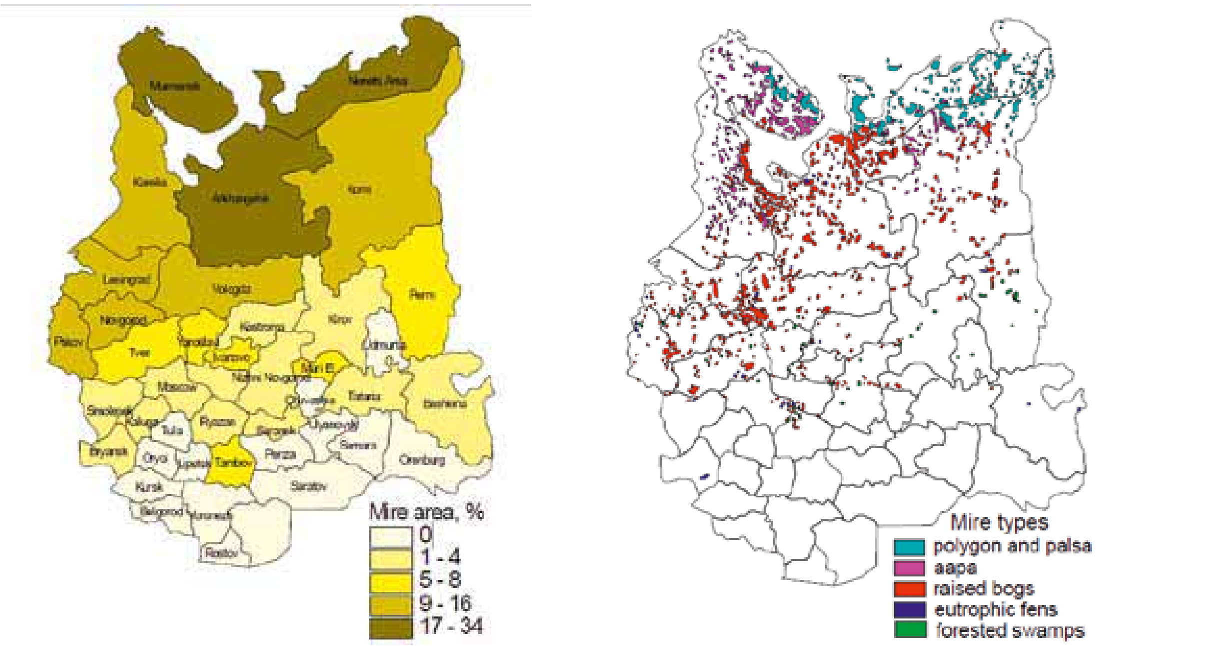


Figure 10: a) Peatland (mire) area within administrative regions of the European part of Russia. b) Distribution of main peatland (mire) types in the European part of Russia (from Minayeva *et al.*, 2009).

Peatland use and degradation

The European part of Russia has a long and intensive history of peatland utilization, which is reflected in a complex administration (Box 11). In the period before 1990, when the Soviet Union was the largest peat extractor of the world, peat extraction was concentrated in the regions with significant peat resources. Nowadays peat extraction has decreased considerably and is largely taking place in areas with local demands for peat. The total area of mined out peatlands in European Russia in 2007 was estimated as 2,309 km^2, whereas 5,294 km^2 were under development (Minayeva *et al.*, 2009).

Whereas in 1967 the area of peatland drained for agriculture in Russia (both the Asian and European part) was estimated as 16,000 km^2, it reached 51,000 km^2 by 1990. According to the latest inventory

Box 11: Peatland administration in Russia

Peatlands in Russia are traditionally registered under different land categories with different legislation status, management and ownership. Peatlands and lands with shallow peat can be found within forest (71.9%), agricultural (14.2%), and industrial lands (0.3%), within settlements (0.3%), within the "water fund" (9.6%), in state reserve lands (11.4%), and in specially protected nature areas (SPNAs, 1.6%). The lands of the State Forest Fund, the Water Fund, the State Reserve lands and the Federal SPNAs are in ownership of the Russian Federation and governed by different authorities. Industrial lands, such as peat excavation areas, are in many cases rented by the companies from the state and thus for this period moved from the other land categories. Agricultural lands were mostly privatized after 1990s and now belong to companies, private farmers etc. While belonging to different land categories peatlands may have additional servitudes to the state which significantly modifies their use and management (Minayeva *et al.*, 2009).

State administration in Russia with respect to peatlands is, however, not yet fixed. The Water Code of the Russian Federation (2006) regards mires as a special water objects and contains a section that exclusively deals with peatland conservation. Of particular concern is the division of responsibilities regarding peatland development and conservation planning between federal, provincial and local levels. Within this context there is a strong need to sustain the framework provided by the Russian Action Plan for Peatlands (2002) and to increase the capacity for integrated management with the emphasis on promoting and supporting intersectoral cooperation and coordination (Minayeva *et al.*, 2009).

(1999-2000), about 30,000 km^2 of drained forests on peatland were registered in the European part of Russia, of which 7,500 km^2 were spontaneously rewetting because of lack of ditch maintenance (Minayeva *et al.*, 2009).

Over the last decades 30% of the agricultural peatland, 25% of the peat extraction areas and more than one third of the forestry peatland have been abandoned. Many of these abandoned peatlands are vulnerable to fire and all are GHG sources. Forest stands on peatlands are mainly over-aged and subject to wind-throw and other degradation processes, which make them vulnerable to fire. In densely populated regions there is a high occurrence of drained peatlands, e.g. in the Moscow oblast where peatlands cover 8% of the area, some 75% (600 km^2) are cut-over, not used and very fire-prone. The peat and forest fires around Moscow in summer 2010 dramatically illustrated this: Peat fires covering only a few km^2 caused more smoke and haze than forest fires ten times larger in area and were the main cause of significant economic and health impacts.

Carbon stock and greenhouse gas emissions
The peat carbon stock in European Russia amounts to some 20 Gtonnes, whereas the drained peatlands in European Russia may annually emit 140 Mtonnes of carbon dioxide (Joosten, 2009), making Russia after Indonesia and the EU the third largest CO_2 emittor from drained peatland worldwide. The Russian peat fires of 2010 may have added a similar amount of CO_2 to the atmosphere (Figure 11).

Opportunities for emissions reductions and enhancement of other ecosystem services
The extensive peat fires of 2010 led to the decision to improve fire prevention in drained peatlands by restoring water management and rewetting. To meet the urgent needs, the Federal Government in 2010 allocated 300 million rubles for partial rewetting 60 km^2 of degraded peatlands in Moscow province. In 2011 the government of Moscow province allocated 80 million rubles for designing works and the Federal budget funded with 1,104 million rubles implementation for an area of 220 km^2. Currently, Moscow oblast is funding design activities (156 million rubles) and the Federal Government has allocated 3.1 billion rubles for implementation on 100 km^2, to be realized in 2012. For 2013 1.5 billion rubles is supposed to be allocated, while Moscow province plans to fund engineering work on an additional area of 120 km^2 at a level of 113.6 million rubles.

Whereas the urgent situation called for immediate action, the Moscow oblast decided that the structural problems of drained peatlands require sustainable, long-term strategies to guarantee socio-economic and environmental security. The latter requires technical assistance and sharing of international expertise. This led to the development of a Russian-German cooperation project with the following innovations:

- development of a standard rewetting procedure and application of the Decision Support System (DSS) for peatland conservation, restoration and utilization in Russia (see Box 12);
- linking project activities to project based finance sectoral or private sector mechanisms: a) under a post 2012 international climate change regime, b) by applying the VSC-PRC standard (see Chapters 3.3 and 4.4) to enable emission offsetting projects from peatland rewetting, and c) by developing Public Private Partnerships on paludiculture with emphasis on Sphagnum farming; and
- development of standards for national emission reduction accounting of peatland rewetting within a post- Kyoto regime, including developing methodologies for assessing emissions from drained and rewetted peatlands by a) verifying the GEST model to use vegetation as a quantitative indicator for emissions (Couwenberg *et al.*, 2011) and adapting it to the Russian situation, b) developing a proxy on the basis of peatland water table, and c) applying remote sensing techniques for large scale assessment (Draft Inception Report, 2012).

Figure 11. Peat fires burning under snow in Russia, November 24, 2010.
Photos: Frank Edom

Ukraine

Peatland distribution
Ukraine (603,700 km^2) comprises circa 14,000 km^2 of peatland (Truskavetskiy, 2010). Most of them are concentrated in the northern part of the country in the huge glacial valley shared with Belarus, the Polessie. The area of peatlands decreases to the south, where peat deposits only occur in river valleys and small depressions. Fens are prevalent and constitute up to 90% of all the peatlands in Ukraine. Few transitional peatlands and bogs occur in the north-western part of Polessie and in the Carpathian Mountains. In Eastern and Western Polessie deposits of 2-10 km^2 are prevalent, in Central Polessie (Kiev and Zhitomir regions) the deposits are smaller (up to 1 km^2).

Peatland use and degradation
About 50% of the total peatland area of Ukraine has been destroyed or severely degraded, about 80% are drained (Mochvan and Vakarenko, 2000). Large-scale drainage of peatlands for peat extraction and agricultural use started in the 19th century. Although peat extraction in Ukraine declined and large-scale agricultural practices were abandoned after 1990, the exploitation of peatlands continued. Small-scale agriculture by local communities is practiced today on the peatlands of former cooperative farms

Box 12: Decision Support System for peatland management in Russia

Since the 1990s, millions of hectares of drained peatland have been abandoned in Russia. Drainage systems, installed 30-50 years ago are, however, still working in many areas leading to dry and uncontrolled peatland sites that

- are vulnerable to peat fires;
- have high GHG emissions; and
- have little economic value with limited competitive economic claims.

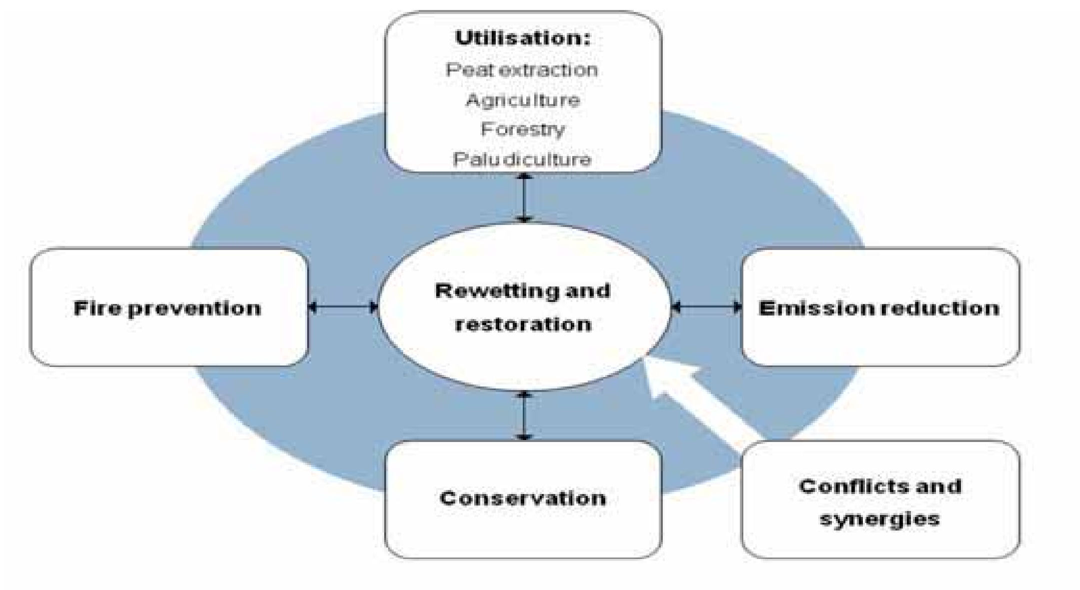
The recurrent, enormous peatland fires in the Russian Federation (2003, 2007, and 2010) stress the urgency to (re-)install proper management. In a project sponsored by the International Climate Initiative of the German Ministry for Environmental Protection (BMU ICI) a project consortium of Russian, German, and Dutch partners developed an implementation strategy for restoring and conserving peatlands in the European part of the Russian Federation. One challenge was to develop a simple tool to support decision makers in identifying priority areas and suitable options for peatland management.

The resulting Decision Support System (DSS, Abel *et al.*, 2011) has a dichotomous structure like similar tools for peatlands, such as DSS-WAMOS (Hasch, 2009) and PMDSS (Knieß *et al.*, 2010). The DSS builds on basic principles in peatland ecology (Joosten and Clarke, 2002), peatland restoration (Joosten and Schuman, 2008; Kozulin *et al.*, 2010), and climate impact of degraded peatlands (Couwenberg *et al.*, 2011). The tool aims at wise decision making with respect to the management of degraded and abandoned peatlands with special attention to reducing GHG emissions and is presented as a bilingual brochure (English and Russian) addressing a broad audience.

The DSS discusses various management (incl. utilization) options, advantages and disadvantages of these options, and conflicts and synergies between these options. The DSS is organized in modules that deal with:

- rewetting to reduce greenhouse gas emissions;
- rewetting to reduce fire hazard;
- nature conservation; and
- utilization / production (peat extraction, agriculture, forestry, and paludiculture).

Interrelations of different aims (production, biodiversity, conservation, climate change mitigation, and fire hazard reduction) are discussed in a conflicts and synergies module.
The brochure can be downloaded from: http://www.succow-stiftung.de/broschueren.html.



(kolkhoz). Small-scale private land use on peatlands is currently more common in the north-west (Rivne and Volyn oblasts), while in the north-east (Chernigiv oblast) many sites are abandoned or only subject to low-intensity cattle grazing (Figure 13). The Peat Cadastre of Ukraine (as of 2003) mentions the following categories of peatlands:

- Registered: 5 265 km^2 of peat deposits
- Explored: balance 2 291 km^2, outside of balance 677 km^2
- Under extraction: 305 km^2
- Agricultural land (reclaimed): 3 084 km^2
- In natural state: 1 026 km^2
- Natural-reserve fund: 713 km^2
- Forest fund: 1 165 km^2
- Under artificial water level: 112 km^2
- In the Chernobyl zone: 25 km^2

Ukraine has no common policy for peatland use, management and conservation. The peatlands used for agricultural purposes are managed under agriculture policy. Abandoned peatlands that were formerly used by cooperative farms (kolkhoz) are unlikely to become rewetted owing to lack of clear and prescriptive legislation. The peatlands used for forestry are managed under forest management. Peatlands allocated for peat extraction are extracted down to a depth of 50 cm of peat and afterwards transferred to agriculture or forestry lands. These peatlands are, however, degraded and not suitable for agriculture or forestry and often abandoned. Some of them are rewetting spontaneously, others stay dry. The extraction companies underlie no legal obligation to rewet these areas after extraction or abandonment.

Carbon stock and greenhouse gas emissions
The estimated peat carbon stock in 2008 of Ukraine is 750 Mtonnes C. With respect to peatland emissions, the country ranks 24th in the world (4.9 Mtonnes CO_2 $year^{-1}$, Joosten, 2009). A methodology for national inventories on peatlands is currently under development within a BMU-ICI project in cooperation with the National Environment Investment Agency of Ukraine, the central executive body for coordinating compliance with UNFCCC and Kyoto Protocol obligations in Ukraine.

Figure 12. Severely degraded and abandoned peatland in the Chernigiv region (Ukraine)
Photo: Hans Joosten

Opportunities for emissions reductions and enhancement of other ecosystem services
In contrast to Belarus where land is only state-owned, drained agricultural land in Ukraine is for 80% owned by private persons and local cooperatives. The parcels are small (2-3 ha) and highly fragmented. Key to successful restoration is to identify and implement innovative mechanisms for land access that allow peatland rewetting on the large scale of hydrological units. The development and realization of regional communication and partnership strategies as well as cooperation models, and local level participatory planning have been imperative. Rewetting of privately owned land also requires officially approved changes in the Oblast Land Use Plans. These plans must define the land management regime of rewetted lands and provide legal restrictions to changing land use of rewetted land in future.

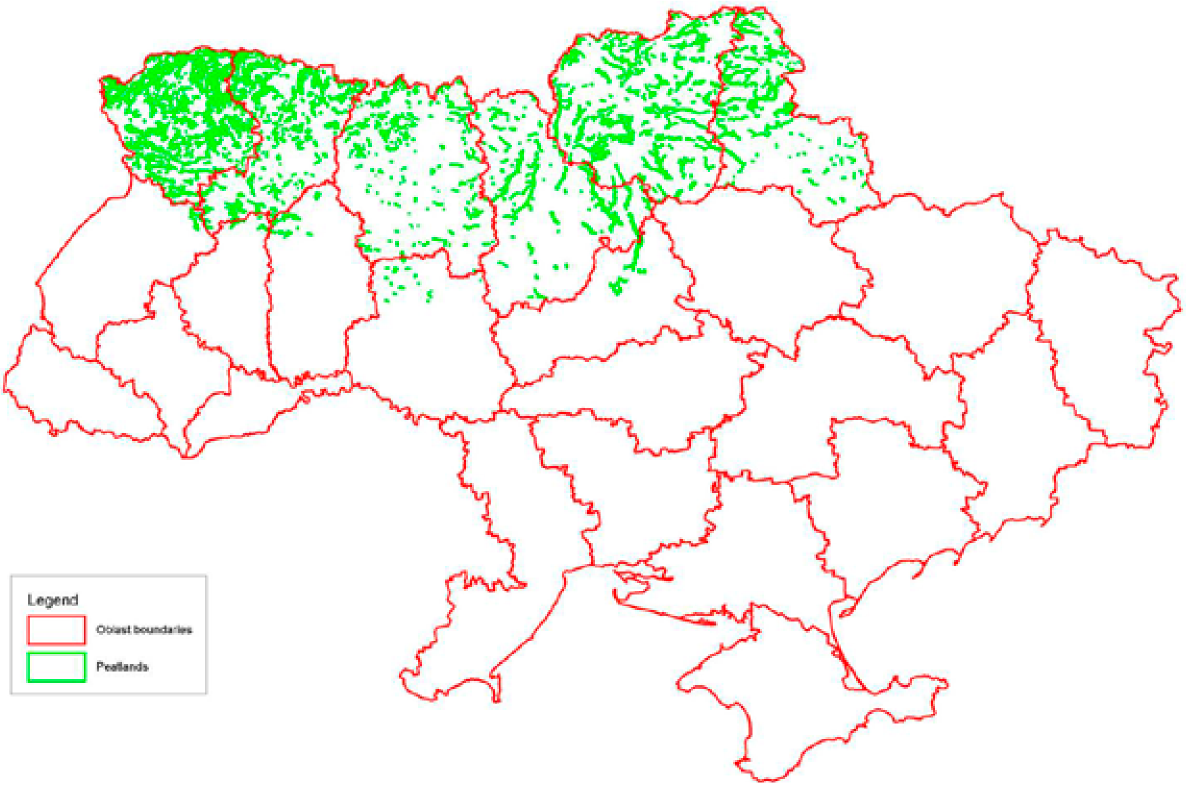


Figure 13: Peatland distribution in Ukraine (from Mikityuk, 2010).

5.4. Central Asia: China and Mongolia

Central Asia is one of the areas where the biggest impacts of climate change are already experienced and to be expected. The peatlands in this area play a vital role in supplying water for food and fuel production and regulating hydrology. Whereas awareness of this pivotal role is increasing, the capacity for peatland restoration and sustainable use has to be improved urgently.

China

Peatland distribution
Peatlands are widespread over China (Figure 14). The total peatland area for China is reported to be 34,770 km^2 (Kivinen and Pakarinen, 1980; Chai, 1980). Additionally an area of 6,820 km^2 of "buried peatland" (i.e. peat covered by other deposits) exists (Chai, 1980). The most important "surface" peatland occurrences in China are:

1. the Sanjiang Plain in Northeast China (Heilongjiang province), formed by the three rivers Heilongjiang (Amur), Songhuajinagg and Wusulijiang (Ussuri);
2. the Daxing'anling and Xiaoxing'anling area, the northernmost part of China, and
3. the Ruoergai (or Zoige) Plateau on the northwestern margin of the Qinghai – Tibetan Plateau (see Box 1), the largest and densest area of peatlands in China (State Forestry Administration P.R. China, 2002).

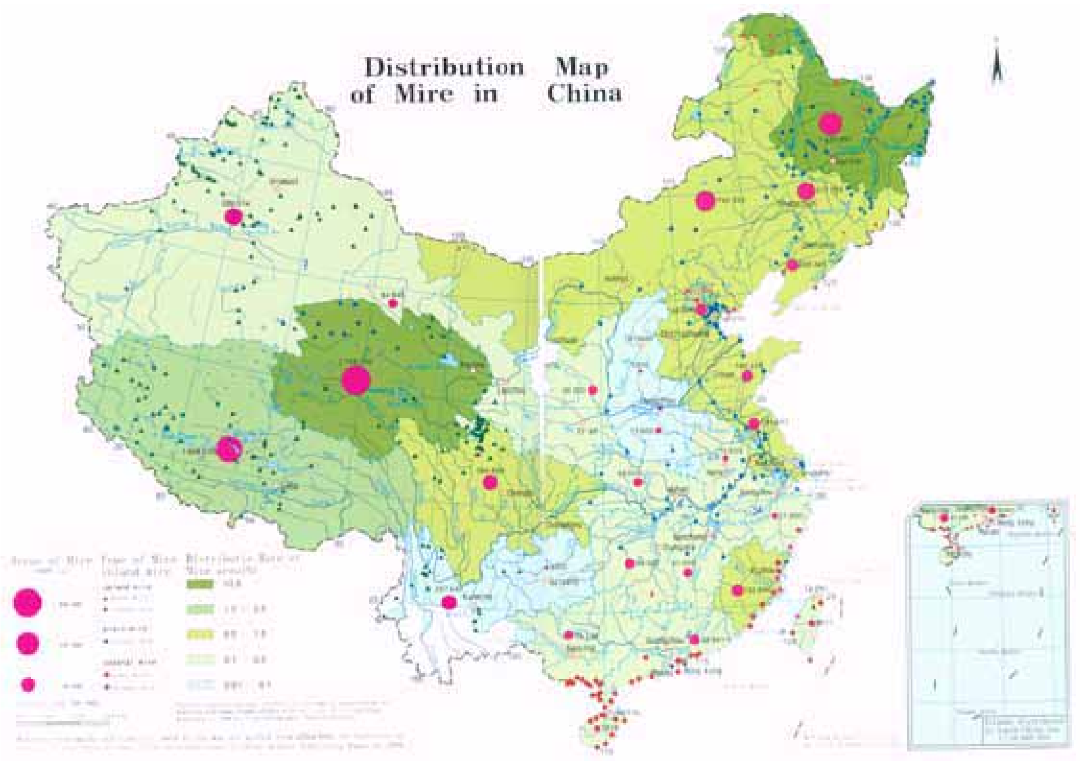


Figure 14: Distribution of “mires” in China (from State Forestry Administration P.R. China, 2002).

Peatland use and degradation
Almost all peatlands in China have been disturbed by human activities to some degree (Yang, 2000b). As early as two hundred years ago China began to drain peatlands for farmland, pastureland and afforestation (Zhang, 2000).

The Sanjiang Plain with a total area of 108,900 km² had originally 24,200 km² of wetland (Kuivi & He, 2000). Huge parts were converted by local farmers, soldiers and “Zhiqing” (urban educated “rusticated” youth) between the early 1950s and the 1970s, responding to the central government’s call to develop the Great Northern Wilderness (“Beidahuang”). Currently the Plain is one of the most important grain production areas in China (cf. Rongfen, 1994). It is also still one of the most important wetland sites in Northeastern Asia from a biodiversity point of view. However, desertification has affected 20% of the land and only 380 km² of peatlands are left in a somewhat natural state (Yang, 2000b).

Since the 1990s, the Sanjiang Plain and northern China have suffered worsening droughts, floods and sandstorms that have been attributed to the shrinking wetlands. Not only do these threaten China’s food and energy security, but – as many water systems reach neighboring Russia – the effects stretch beyond China’s borders.

Figure 15: Distribution of good quality (black) and degraded peatlands (grey) on the Ruoergai Plateau (from Schumann *et al.*, 2008).

On the Ruoergai Plateau, peatlands cover almost 5,000 km² (= 17% of the land). Over 2,000 km² is drained, 60% overgrazed and desertification affects large areas (Yang, 2000b; Chew, 2003). Good quality peatlands still cover 1,100 km^2 (23 % of the peatland area) but 3,600 km^2 (77 %) must be considered as degraded (Schumann *et al.*, 2008; Figure 15). Comparison of the 1977 and 2007 situation (Table 12) shows, that in the last 30 years the area of degraded peatland has almost doubled. Large parts were already degraded in 1977, illustrating that grazing had made the peatlands prone to degradation long before recent intensification of peatland use (Joosten *et al.*, 2008; Box 1).

Table 12. Areas of "good quality" and "degraded peatland" on the Ruoergai Plateau in 1977 and 2007 (Schumann *et al.*, 2008).

1977	2007	Area (km^2)	%
degraded peatland	degraded peatland	1,919	41
good quality peatland	degraded peatland	1,718	36
good quality peatland	good quality peatland	811	17
degraded peatland	good quality peatland	285	6
	Total	4,733	100

Carbon stock and greenhouse gas emissions

The peatland carbon stock in China is estimated on 3.2 Gtonnes, the peatland CO_2 emissions on 77 Mtonnes per year, bringing China in the global top-five of peatland CO_2 emitters (Joosten, 2009). Because of drainage, methane emissions from wetlands and peatlands have substantially decreased since 1949, especially in Northeast China (Xu and Tian, 2012).

Opportunities for emissions reductions and enhancement of other ecosystem services

The environmental and economic problems associated with peatland drainage have in recent years been recognized by the national and provincial governments. Priorities for action have been identified in the Chinese National Wetland Conservation Action Plan (State Forestry Administration, 2002) and ambitious restoration projects have started and are being implemented, of which first results are beginning to show.

On the Ruoergai Plateau, the authorities have introduced a ban on draining wetlands, started to fill in drainage ditches, and designated five nature reserves covering about 5,000 km^2. The rewetting of large expanses of peatlands has already resulted in a substantial improvement of the local peatland condition (Schumann and Joosten, 2007).

In Heilongjiang, designated as one of the three environmental provinces in China, the provincial government is looking for development opportunities that integrate watershed and wetland management in a sustainable way. A pioneer of wetlands protection in China, the provincial government has banned any cultivation and excavation of wetlands since 1999. 1,500 km^2 of farmland are planned to be restored to wetland and 685 km^2 replanted (Yu, 2009).

In the Sanjiang Plains Wetland Protection Project (2006–2012, financed by the Asian Development Bank), watershed management is being addressed in a holistic way by (i) protecting forests and rehabilitating degraded forests in the upper watershed areas, (ii) protecting and restoring wetlands in the downstream areas, (iii) providing alternative livelihood to farmers, and (iv) strengthening the capacities of local agencies in charge of watershed wetland and nature reserve management (de Silva and Senaratna Sellamuttu, 2010).

For China it is clear that to maintain and restore the vital environmental functions of peatlands and wetlands – as a basis of securing food and fuel production, especially outside of the wetlands themselves – the remaining, good quality peatlands must be protected and degraded peatlands must be restored (e.g.by implementation of paludicultures). The most important challenge now is to increase awareness among decision makers and general population on the important landscape ecological role of peatlands and to enhance long-term capacity in integrated landscape and watershed management.

Identifying drained peatlands suitable for paludicultures in Jilin,Northeast China.
Photo: Shen Li.

Mongolia

Peatland distribution

Generally considered as a country of steppes and deserts, Mongolia has an amazing diversity and expanse of peatlands. There are brown moss-rich sedge fens in river valleys and intermontane depressions, sedge-cottongrass fens on permafrost, blanket bogs on mountain heights (2500–3200 m) with sphagnum and/or brown mosses and arctic sedges. In the taiga zone of the Khentay Mountains raised bogs with a peat layer up to 4–5 meters thick occur along with coniferous forests on shallow peat on gentle slopes, whereas in the forest-steppe zone of the Khentay Mountains fens with birch and dwarf willows, as well as spring mires with very high floristic diversity are found. Minayeva *et al.* (2004) estimate the total area of peatlands in Mongolia on 272,000 km^2, being 1.74% of the area of the country (Figure 16).

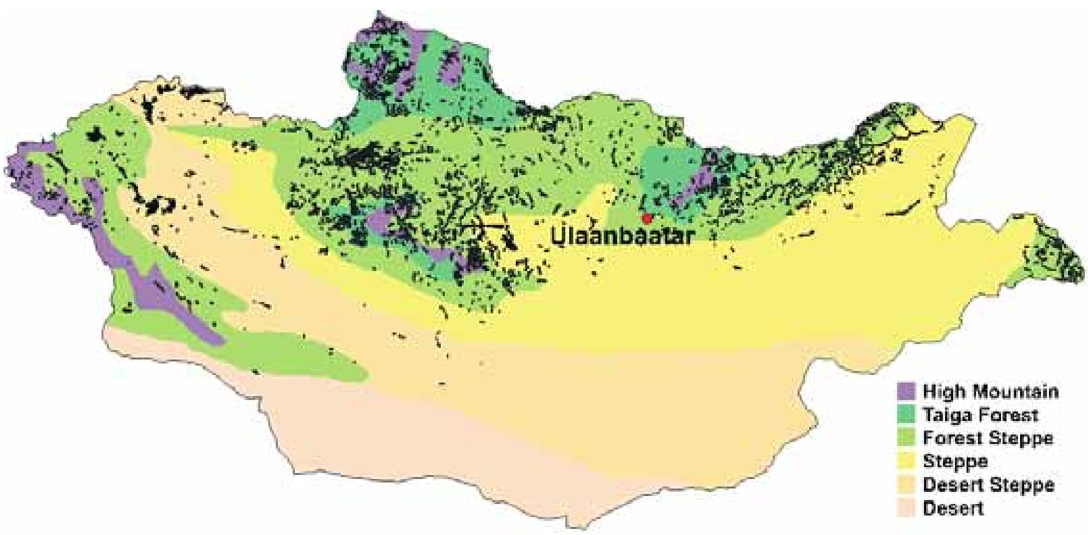


Figure 16: Peatland distribution in Mongolia (from Minayeva *et al.*, 2004)

In Mongolia peatlands constitute the last wet habitats in a major part of the country. They maintain wet habitats and pastures, feed rivers, prevent soil erosion, maintain levels of groundwater necessary for forest and crop growth, and keep wells full of water. During dry periods – which may continue for years – the moisture preserved in peatlands is really a source of life and a barrier to desertification (Minayeva *et al.*, 2005).

Peatland use and degradation
Peatlands are mainly used for grazing and sometimes as arable land. They belong to the most productive pasture areas in Mongolia and all sedge fens in river valleys are currently being grazed. The stimulation of private cattle husbandry and consequent overgrazing in recent years has led to severe losses in productivity. Combined with recent climate change, overgrazing and human induced fires have led to the loss of – for example – thousands of hectares of fens in the Orchon and Ider valley and the Darchat intermontane basin. Large flat areas here currently show denude dry peat without vegetation. During storm surges the unprotected peat is moved downhill causing rapid loss of peatlands and progressing desertification. Old maps, native population and literature data described these areas – e.g. in the Orchon River valley (Lavrenko, 1956), as covered with vast mires, very wet and impassable, but only poor remnants of these landscapes are left (Minaeva *et al.*, 2003, 2004).
The main direct threats for Mongolian peatlands are overgrazing, gold mining, and – in the piedmont regions of the northern Khentay Mountains – conversion to arable land. Peatlands are occasionally destroyed during road construction and gold panning in rivers (Minayeva *et al.*, 2005).

Carbon stock and greenhouse gas emissions
According to the IMCG Global Peatland Database, the peatlands of Mongolia contain 750 Mtonnes of Carbon and emit 45 Mtonnes of CO_2 per year. This brings Mongolia in the top-ten of peatland-CO_2 emitters of the world (Joosten, 2009).

Opportunities for emissions reductions and enhancement of other ecosystem services
Currently, mires are preserved within a number of nature reserves and Ramsar sites in Mongolia. There are no special protected areas devoted to mire protection, nor is there special site management regarding peatlands (Minayeva *et al.*, 2005).

Desertifying dry peatland in Tesiin Gol River valley, Mongolia, where mire vegetation and (up to one meter deep) peat deposits only remain in depressions. The surrounding vegetation is typical for steppe and steppe-desert.
Photo: Andrey Sirin.

Mongolians have lived for thousands of years in harmony with peatlands. However, global changes have thrust people into circumstances in which traditional knowledge is no longer comprehensive. The main threat to peatlands in Mongolia is the absence of detailed knowledge about their diversity, distribution and natural functions. Land use planning should base on solid knowledge about the role of peatlands in the landscape (Minayeva *et al.*, 2005). Peatland use should apply the principles of wise use, as recently have been introduced in the Har Us Nuur National Park Ramsar site (Western Mongolia) by the WWF's Altay-Sayan project.

5.5. Africa: Congo Basin and Uganda

In the regions discussed before there is a fair knowledge on the distribution and status of peatlands. Southeast Asia has recently attracted much scientific attention because of the rapid destruction of the peatland resource and the associated environmental problems. In Europe, peatlands have been used for agriculture, forestry and peat extraction already for hundreds of years and as a result an extensive knowledge base exists. In contrast, there is a serious lack of knowledge about the peatlands in the heart of Africa (Figure 17).

Here we discuss the Congo basin, an area where enormous stretches of peatlands must exist that have remained largely unnoticed until now. Also Uganda has large areas of peatlands that are currently under heavy pressure and of which a substantial part has been drained in recent times, making Uganda the major peatland CO_2 emitter of the African continent (Joosten, 2009).

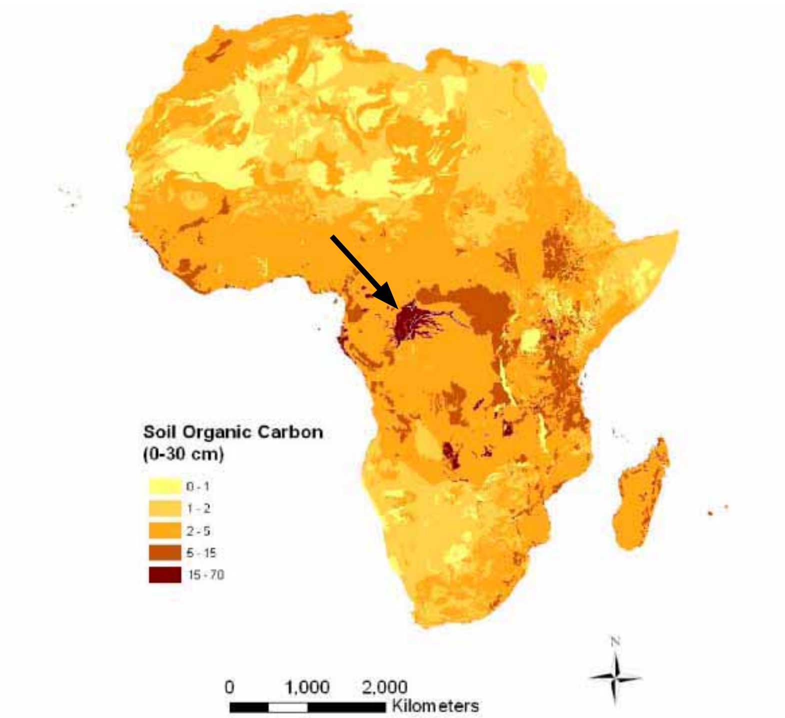


Figure 17. The soil carbon content of Africa (from Henry *et al.*, 2009). Blue arrow marks the central Congo Basin.

Congo basin

Peatland distribution

The equatorial Congo Basin constitutes the second largest river basin on Earth. The 4,374 km long Congo River drains a catchment of 3,747,320 km^2 (Runge, 2008) that receives high annual rainfall (of over 1,600 mm) in its central part (Campbell, 2005). Vast stretches of swamp forest occupy the central part of the Congo River Basin – the so called cuvette central congolaise. This region extends over 1,176,000 km^2 (Bwangoy *et al.*, 2010), comprising almost 30% of the Congo Basin catchment and is shared by the Republic of Congo and the Democratic Republic of Congo (DRC). The rivers of the cuvette central congolaise have an exceptionally low gradient of 3 cm km^{-1}. These rivers are also characterized by a low range of annual water table fluctuations compared to other tropical rivers such as the Amazon (Campbell, 2005).

This hydrological setting allows for substantial water retention on the interfluves and sustained flooding of swamp forest. Peat accumulations of up to 17 m have been reported but the general thickness is apparently not more than one meter (Evrard, 1968; Campbell, 2005). The knowledge on the peatland area of the central Congo Basin is, however, very poor. Permanently flooded forests reportedly occur in depressions with flooding levels of 4 m whereas seasonally flooded forests occur higher on the upper floodplain with water table of between 2 and 4 m above ground (Campbell, 2005; Vancutsem *et al.*, 2009). The partly convex surface between adjacent rivers, as can be surmised from digital elevation models, may in fact be formed by interfluvial peat domes (Figure 18). Evidence of sustained flooding of organic deposits comes from methane flux measurements of flooded forests, which indicate high annual emissions of between 1.6 and 3.2 Mtonnes for the entire swamp forests of the Congo Basin (Tathy *et al.*, 1992).

Figure 18: Congo: Interfluvial swamp forest between the Likouala aux Herbes (left) and the Ubangui River (right) directly on the Equator. The interfluve (space between the rivers) is 30 km wide. The swamp forest shows different zones. Reddish colour of the Likouala aux Herbes floodplain is swamp grassland. Image taken from Google Earth.

The knowledge of the prevailing vegetation types in the Congo Basin has recently been much advanced by remote sensing studies (e.g. Mayaux *et al.*, 1999, 2000, 2002; De Grandi *et al.*, 2000; Vancutsem *et al.*, 2009; Bwangoy *et al.*, 2010). In DRC wetland forest types together cover 102,452 km^2 whilst aquatic grassland occurs over an estimated area of 5,261 km^2 (Vancutsem *et al.*, 2009). One of the most recent wetland mapping efforts for the cuvette central congolaise combined the use of radar, topographic and thematic remote sensing data (Bwangoy *et al.* 2010, Figure 19) and arrived at an overall wetland area of 359,556 km^2 (or ~36 million ha) for the central Congo Basin. Most wetlands are located in the Lac Télé-Lac Tumba region (207,467 km^2, 56%) and east of Lake Mai-Ndombe. The huge area of these wetlands – largely flooded forests – may contain a substantial below ground carbon stock.

Peatland use and degradation
In contrast to the forested peatlands of Southeast Asia, logging intensity is much lower in the Congo Basin wetland forests (Hansen *et al.*, 2008). Commercial scale logging or agricultural conversion to plantations has not yet happened in the cuvette central congolaise. Small scale logging is done by local people for shifting cultivation, but the generally low population density prevents from wider degradation. Catastrophic events such as fires have not been impacted this forest due to the low or widely absent human influence.

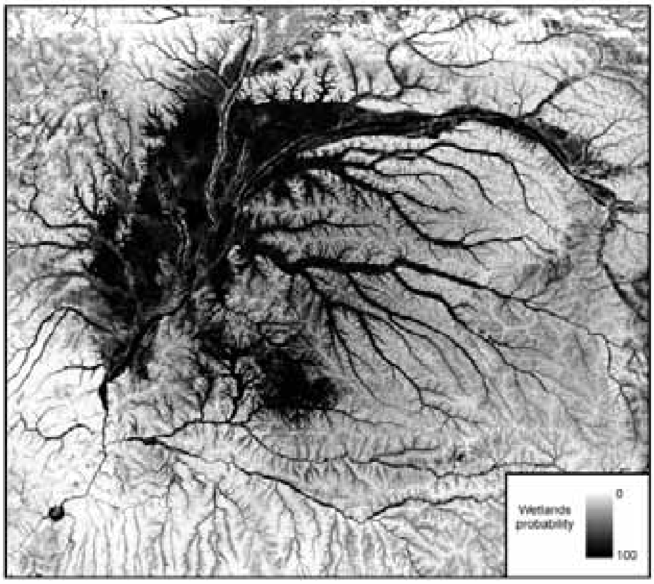


Figure 19. Wetland probability map of the central Congo basin (from Bwangoy *et al.*, 2010).

Carbon stock and greenhouse gas emissions
Existing estimates on soil or peat carbon are not giving notable figures. For the Republic of Congo Schwartz and Namri (2002) estimate a soil carbon stock in the upper two meters of only 134–160 tonnes ha^{-1} for the flooded forests of the Congo Basin and of 276–456 tonnes ha^{-1} for the swamp grasslands along the rivers. These authors report a soil carbon stock for the entire country of 3.9 Gtonnes in the upper 2 m. Page *et al.* (2011) estimate the peat carbon stocks of the Republic of Congo at 2.35 Gtonnes and that of DRC at only 0.56 Gtonnes (combined 2.9 Gtonnes C). Henry *et al.* (2009) report country based estimates of soil organic carbon for the upper first meter. For Republic of Congo they give 9.3 Gtonnes C and for DRC 21.9 Gtonnes of carbon. Although not focusing on peat, their soil carbon map for Africa shows the highest soil carbon density in the central Congo Basin (Figure 17).

Assuming that just half of the central Congo Basin wetland area (180,000 km^2) is covered by one meter thick peat with a carbon density of 0.05 g cm^{-3} (0.05 tonnes m^{-3}) would yield a peat carbon stock of 9 Gtonnes alone. The soil carbon reservoir of the Congo basin wetlands might be substantially underestimated. Better knowledge on the extent and depth of peat and consequently on the soil carbon stock would require substantial ground truthing in this huge and hardly accessible area.

Opportunities for emissions reductions and enhancement of other ecosystem services
The current situation of limited human impact is no guaranteed that major forest degradation or destruction would not happen in the future. Southeast Asia and Amazonia have experienced massive and rapid deforestation within short periods although these areas were long seen as impenetrable areas. The search for valuable resources such as metals or oil could cause forest destruction in even deeply flooded wildernesses. Any large-scale impact on the vegetation, soils or hydrology could cause irreversible ecosystem degradation and large quantities of carbon losses. Fast incentives are needed now to further protect these unique forests and to do inventories of their natural resources, particularly their carbon stock are needed now, before destructive industries may open up this vast tropical wetland region. As a habitat for lowland "swamp" gorillas and chimpanzees, the cuvette central congolaise is also of global importance for biodiversity conservation (e.g. Blake *et al.*, 1995).

Uganda

Peatland distribution
The total wetland area of Uganda is estimated at 30,105 km^2 (13% of total land area) of which 22,809 km^2 or 72 % are classified as seasonal wetland (Figure 21). Permanent wetlands cover 7,296 km^2 (24%) or 3 % of the country and occur from the low-lying lake basins to the alpine zone of the highest mountains (Figure 22). Papyrus (Cyperus papyrus) swamps represent the largest portion of the permanent wetlands. Papyrus forms both floating swamps along the lake margins and valley swamps in steeper terrain (Carter, 1956). Floating papyrus swamps are particularly common along the northwestern shore

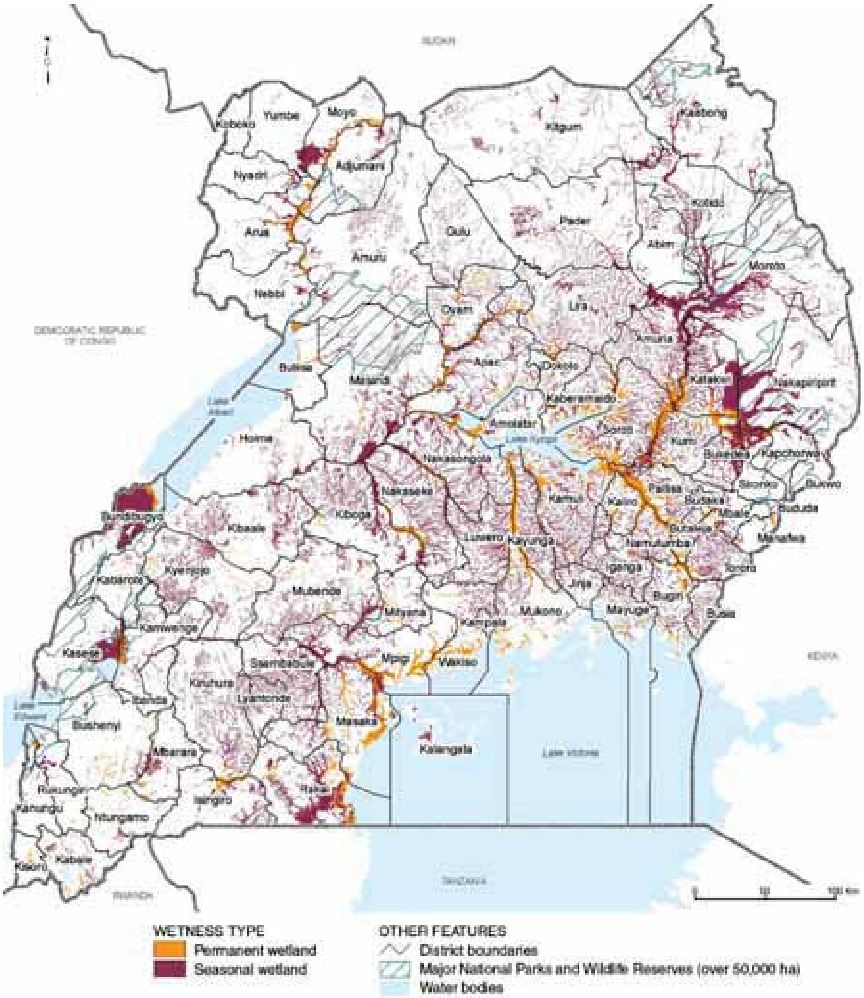


Figure 20: Distribution of permanent and seasonal wetlands in Uganda in 1996. Retrieved from: http://www.wri.org/map/uganda-distribution-permanent-and-seasonal-wetlands-1996

of Lake Victoria, at Lake Kyoga, Lake Bunyonyi and Lake Albert (Figure 21).
Under the floating mats plant detritus sinks to the lake bottom to form "peat gyttja" that can fill shallow waters. According to Beadle (1974) these peats are not thicker than 2–3m whereas – in contrast – Morrison (1968) based on numerous coring trials, states that the Papyrus (and grass) swamps below 1600 m largely do not contain peat. Swamps of Papyrus are also common in the Kigezi highlands of SW-Uganda where they reach peat depths of up to 20 m (Taylor, 1990). Seasonally inundated swamps are typically dominated by grasses, desiccate during the dry season and do not accumulate peat (Beadle, 1974; Lind and Morrison; 1974; Thompson and Hamilton, 1983).

Figure 21: Pristine peatlands in Uganda: Papyrus swamps in the Nile delta of Lake Albert (left), Carex peatland on Mt Elgon (middle) and highland valley Muchoya swamp (right).
Photos: left and middle: Rene Dommain, right image taken from Google Earth.

The Ministry of Energy and Mineral Development estimates the peatland area of Uganda at 4 000 km^2 (NEMA, 2008) much less than reported in other sources (Page *et al.*, 2011, Joosten, 2009; Shier, 1985). This figure is though in accordance with the large proportion of seasonally dry swamps and Morrison's (1968) observation of limited peat accumulation in the lower altitude Papyrus swamps.

Peatland use and degradation

The most densely populated areas of Uganda, the Lake Victoria basin and southwest Uganda, have experienced the largest wetland losses (e.g. Kisoro and Jinja districts, NEMA, 2008). Studies on draining Papyrus peatlands in southwest Uganda were already performed in the 1950s (Harrop, 1960). These experiments led to extreme acidification (pH 2.4–2.7) after even slight drainage of 30 cm and to the formation of sterile acid sulphate soils as a result of high sulphur contents of the fen peats (Harrop, 1960). These drained swamps could only be cultivated after intense liming and fertilization. Nevertheless, many swamps in the Kigezi highlands were reclaimed for small-holder agriculture with European drainage techniques. Typically these peatlands are cultivated with sweet potatoes, sorghum and maize, but also with peas, cereals and legumes (e.g. Lind and Morrison, 1974; Thompson and Hamilton, 1983). Small fields are established between rib-drains resulting in densely drained peatlands.

Another problem of these valley swamps is erosion and burying of peat from cultivated valley slopes (Pajunen, 1996). Swamp forest has by now disappeared from most valley peatlands due to agricultural encroachment (Taylor, 1990). The Papyrus swamps around Lake Victoria have often been converted to cocoyam (Colocasia esculenta) fields which leads to CO_2 losses (Saunders *et al.*, 2012), to lower nutrient retention capacity and to higher pollution of Lake Victoria (Kansiime *et al.*, 2007).

Figure 22: Densely drained peatlands in SW Uganda: in the Kisoro District (left) and Ruhuma Fen (Kabale District) (right). Ruhuma Fen was largely converted since 2003 (Sliva, 2005) (Images taken from Google Earth).

Carbon stock and greenhouse gas emissions

The peat volume of Uganda is estimated at 60 billion m3 (NEMA, 2008). This volume together with a mean bulk density of 0.1 g cm3 (NEMA 2008) and a carbon content of 50% would yield a peat carbon stock of 0.3 Gtonnes. This C stock is substantially lower than reported values of between 1.3 and 1.5 Gtonnes C (Joosten, 2009; Page *et al.*, 2011).

Whether the vast papyrus swamps along Lake Victoria and the Nile basin have substantial peat deposits needs to be investigated more rigorously. Recent eddy-covariance studies by Saunders *et al.* (2007, 2012) and Jones and Humphries (2002) report exceptionally high carbon sequestration rates from Ugandan and Kenyan lake-edge Papyrus swamps ranging from 480 g m^{-2} yr^{-1} to 1600 g m^{-2} yr^{-1}. These rates are an order of magnitude higher than long-term carbon accumulation rates derived from peat cores from Rwandan Papyrus swamps (78–112 g C m^2 yr^{-1}, Pajunen, 1996) and suggest substantial peat accumulation under floating Papyrus swamps at present. Perhaps, the C4 plant Papyrus already benefits from the higher atmospheric CO_2 content. Longer eddy-flux measuring campaigns combined with peat core studies are truly needed to clarify the current status of undisturbed Papyrus swamps as significant carbon sinks.

Disturbance or conversion switches Papyrus swamps, and other peatlands, into carbon sources (Saunders *et al.*, 2012). In the 1990s 7.3% (~2200 km^2) of Uganda's wetlands were converted (NEMA, 2008, cf. Figure 22). The population of Uganda doubled between 1990 and 2011 from 16 to over 32 million people (UBOS, 2012). It is therefore likely that also the area of reclaimed wetland has doubled to about 5,000 km^2 today. Joosten (2009) estimates the emissions from drained peatlands in Uganda on 20 Mtonnes per year, being the largest emissions of all African countries.

Opportunities for emissions reductions and enhancement of other ecosystem services
The peatlands of Uganda are subject to intensive and increasing agricultural use. The observed environmental problems associated with peatland drainage can be reduced through avoiding further reclamation, restoring degraded sites and implementing paludicultures. The highly productive Papyrus has long been used for roof thatching, matting, or constructing fishing-floats (Beadle, 1974) and appears to be an ideal plant for sustainable use of undrained peatlands.

Drained peatland used for agriculture in West-Uganda.
Photo: Marcel Silvius

5.6. Amazon Basin: Brazil, Guyana Shield and Peru

The drainage area of the Amazon Basin covers more than one third of the South American continent and is shared by Bolivia, Brazil, Colombia, Ecuador, Guyana, French Guiana, Peru, Suriname and Venezuela, with Brazil covering approximately 70% of the area. Amazonia sensu stricto covers an area of 5,569,170 km², whereas the Guiana subregion covers an additional 970,160 km² (Eva and Huber, 2005; Figure 23).

Figure 23: The delimitation of Amazonia sensu stricto (dotted line) and four peripheral subregions Guiana, Andes, Planalto and Gurupí (from Eva and Huber, 2005).

No comprehensive surveys on the area of peatlands or organic soils exist for the huge area of the Amazon Basin. Parts have, however, been subject of case studies combining satellite imagery and ground truthing, of which the results were extrapolated to the entire basin. According to Junk *et al.* (2011) some 30% of the 7 million km² large Amazon Basin comply with international wetland definitions. All wetlands with stable water levels store organic material.

Extrapolating from the Western Amazonian situation, Schulman *et al.* (1999) estimate Amazonia to hold 150,000 km² of peatlands, consisting of Mauritia swamps, open wetlands in floodplains, small swamps in creek valleys, rain-fed mires both in uplands and river floodplains, and nutrient-rich open peatlands in flat upland areas (Ruokolainen *et al.*, 2001; Lähteenoja *et al.*, 2009).

Brazil

Peatland distribution
Peat deposits have been reported to occur regularly along the major river systems of the Amazon Basin (Shrier, 1985; Shimada, 2005), especially in abandoned meanders and oxbow lakes (Franchi *et al.*, 2004). A map of Sieffermann (1988) shows major peatland areas along the Amazonas, Manaos, Madeira and Belem rivers and along the Rio Negro. Innumerable smaller peatlands can be assumed to exist within the rainforests of the Amazon Basin (Schulman *et al.*, 1999; Ruokolainen *et al.*, 2001; Lähteenoja *et al.*, 2009a).

The total area of peatland in the Brazilian Amazon is, however, unclear, with estimates ranging from 15,000 km² (Bord na Mona, 1985; Andriesse, 1988), via 15,000–35,000 km² (Mattar and Delazaro, 1980; Suszczynski, 1981; Lappalainen, 1996) and 40,000 km² (Schulman *et al.*, 1999) to 55,000 km² (Ruokolainen *et al.*, 2011). The 55,000 km² estimation (based on available publications, field observations, land cover maps and satellite imagery) claims to be a rough, conservative and probably the best available estimate for this area. It is clear that more comprehensive and reliable data on the location and extent of peatlands in the Brazilian Amazon are urgently needed.

New remote sensing applications have already revealed the existence of extensive peat domes (Figure 24) illustrating that the peatland area of the Brazilian Amazon may be conspicuously larger than currently known.

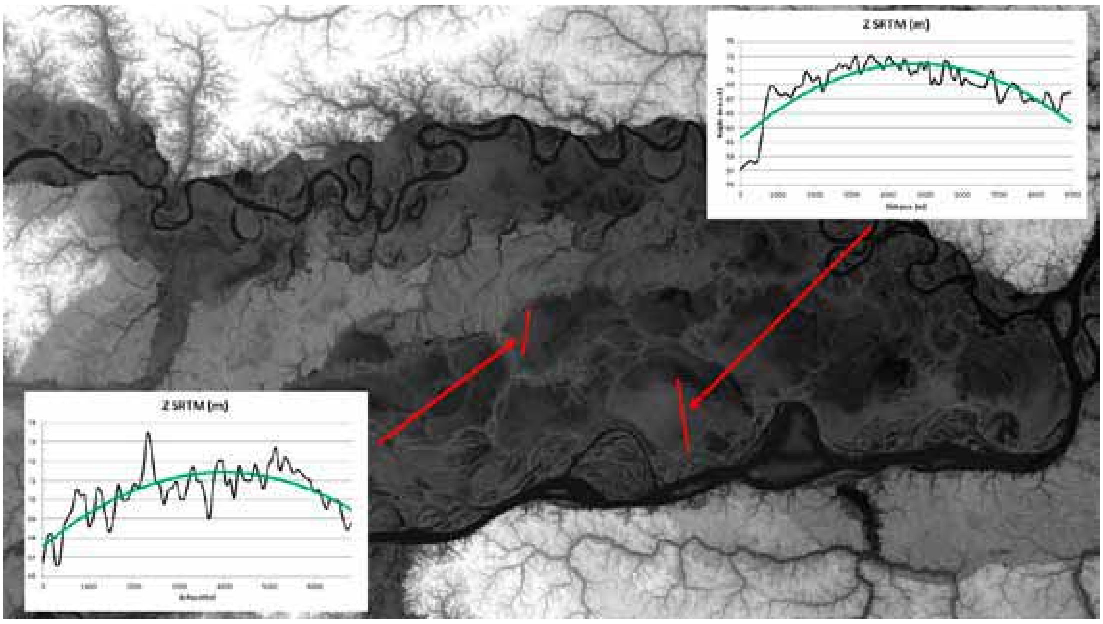


Figure 24: Peat domes of the Central Amazon between the Amazon and the Putumajo River prospected with optical satellite imagery, SRTM (topographic information), and satellite LiDAR data (ICESat/Glas). Graphs show the polynomial regression curve illustrating the convex shape (cf. Jaenicke *et al.*, 2008). Unpublished data provided by Florian Siegert and Uwe Ballhorn, RSS - Remote Sensing Solutions GmbH, 2012.

Peatland use and degradation

Except for peat extraction (Couch, 1993; Franchi *et al.*, 2004; Shimada, 2005), no systematic data are available on the use of peatlands. Lappalainen (1980, 1981) described peatlands in the Paraiba river valley that were all drained and used for agriculture or as pasture. According to Markov *et al.* (1988) about 3,140 km^2 of peatland has been drained, mostly for agriculture (Figure 25).

Figure 25: Vegetable growing on beds, by Japanese settlers on 1.5 m thick peat in Brazil, practicing sprinkler irrigation to prevent desiccation. Note the original primary forest in the background (From Andriesse, 1988).

Carbon stock and greenhouse gas emissions

According to the IMCG Global Peatland Database, the peatlands of Brazil contain some 5.5 Gtonnes of Carbon and emit 12 Mtonnes of CO_2 per year (Joosten, 2009).

Opportunities for emissions reductions and enhancement of other ecosystem services

The priority for Brazil should be a detailed inventory on the distribution of the country's peatlands, their use and degradation stage. Such information is crucial to set up management plans for pristine or moderately degraded sites, alternative land-use options for drained or cultivated peatlands and for the quantification of peatland carbon losses.

Peru

Most of the Peruvian Lowland Amazon (< 500 m.a.s.l.) consists of alluvial plains. The main rivers in the area are the Amazon (Solimõnes) and the Marañon. Swamps occur in areas with incomplete drainage, such as inactive channels (oxbow and serpentine swamps or lakes), tributary valleys; poorly drained floodplains depressions or in valleys and depressions in the terra firme, i.e. beyond the area presently flooded by rivers (Kalliola *et al.*, 1991). The main vegetation types are palm swamps (with Mauritia flexuosa, Figure 26), shrub swamps and herbaceous marshes.

Peatland distribution

Until the end of the twentieth century hardly any information was available on peatlands of the lowland Peruvian Amazon, but recently the knowledge base has conspicuously improved. Schulman *et al.* (1999) give an area of Mauritia flexuosa swamps of 47,140 km^2 (cf. ONERN, 1986) and assume, supported by fieldwork, that the peat deposits in these swamps are often more than one meter thick. Ruokolainen *et al.* (2001) estimate the peatland area of the Peruvian Lowland Amazon to be 50,000 km^2. Lähteenoja *et al.* (2009b) found frequently peat deposits in this area with some being notably thicker than previously reported from anywhere in Amazonia (cf. Junk, 1983; Suszczynski, 1984; Shier, 1985; Andriesse 1988). For the Pastaza-Marañon foreland basin (120,000 km^2) the total peatland area is assumed to be 43,860 km^2 with a total carbon stock of 6.2 Gtonnes (Lähteenoja *et al.*, 2011).

Figure 26: Mauritia flexuosa peatland in the Peruvian Amazon.

The Guyanas

The Guyana subregion is bordered in the north by the Atlantic coast and the Orinoco and Vichada rivers, whereas the southern limit is formed by the watershed of the Amazon River Basin (Eva and Huber, 2005). It comprises the Guiana region of Venezuela, parts of Colombian Amazonia, French Guiana, Guyana, Suriname and the northern part of the state of Amapá in Brazil. No comprehensive and reliable data on the extent of peatlands or organic soils are available for this region.

The coastal zone of the Guyanas forms part of an uninterrupted low and wet area that ranges from the Orinoco delta (Delta Amacuro) to the Amazon mouth. Large areas with peat soils occur here, especially in the northwest region of Guyana (ter Steege and Zondervan, 2000). While peat depths range up to 9.0 m, the average depth is less than one meter meter (Shrier, 1985).
Mangrove forests occur in a narrow belt of a few kilometres wide along the coast and along the banks of the lower reaches of rivers. In permanently flooded areas of flat plains in the coastal zone, swamp forests can be found. Their poorly drained soils often consist of peats over coastal clay (ter Steege and Zondervan, 2000). More inland, where the duration of flooding is less pronounced, seasonally flooded palm marshes and swamp forests occur. Also in these areas peat may have been deposited.

The extensive "White sand" areas of Guyana, Suriname and French Guiana have a gently rolling aspect and are drained by many blackwater streams (ter Steege and Zondervan, 2000). The water table in the heads of such streams is permanently high and often a swamp forest is found on a layer of peaty soil. Beside these shallow peat areas a number of vast swamps exist where drainage is so slow that the peat grows above sea level. These areas of "ombrogenous peat" can be recognized on aerial photographs by their characteristic radial drainage pattern (Brinkman and Pons, 1968).

French Guiana

French Guiana is very humid and about twenty rivers enter the Atlantic Ocean along the 320 km of lowlands, which have a maximum width of 50 km at Pointe Behague and a minimum width of 5 km east of Cayenne (Prost and Loitier, 1989). Important wetlands occur only in this coastal strip and cover an area of 3,380 km² (Scott and Carbonell, 1986). Vast (also permanent) marshes, mangroves and swamp forests are known from the estuaries of the Sinnamary, Iracoubo and numerous smaller rivers, the Mahury, Approuague and Kaw Rivers, and of Pointe Behague and the lower Oyapock River (Scott and Carbonell, 1986, Figure 27a). These wetlands include large areas covered by so-called 'pegasse' (freshwater peat), which can be 1–2 m thick (Boy, 1959). Saline soils and clays prevail close to the Atlantic coast whereas farther inland large peat areas occur. Adjacent lateritic soils mark the change towards the non-hydromorphic areas of interior French Guiana (cf. Figure 27b).

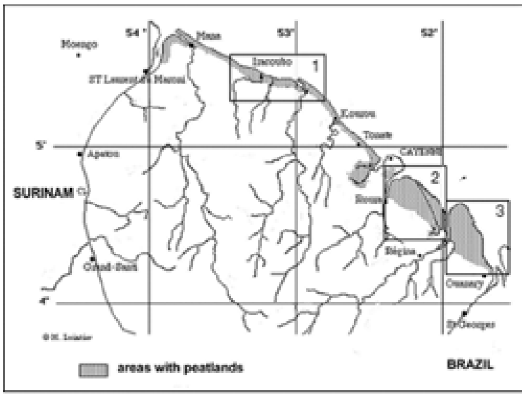


Figure 27a. Major wetlands of French Guinea. Rectangles mark wetlands which include larger peatlands: 1: Estuaries of rivers Sinnamary, Iracoubo and numerous smaller rivers; 2: Kaw Marshes: estuaries of the Mahury, Approuague and Kaw rivers; 3: Estuary of river Oyapock on the Brazilian border. (After Lointlier, 1996 and Scott and Carbonell, 1986.)

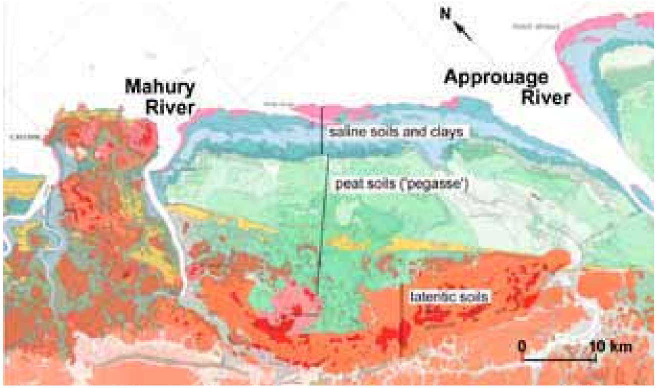


Figure 27b. Soil map of part of the Kaw Marshes in French Guiana. Lightgreen areas are covered by shallow peats (after Fond Topographique and the Carte géologique de la Guyane Francaise au 1/100.000, Office de la Recherche Scientifique et Technique Outre-Mer ORSTOM, section pédologie de l'Institut Français d'Americanique Tropicale).

Shrier (1985) referring to the FAO/UNESCO 1971–1981 Soil Map of the World deduced from the Histosol area a "mire area" of 1,620 km^2 for the coastal swamps of French Guiana. The interpreted World Soil Map arrives at an almost similar estimate of 1,720 km (Van Engelen and Huting, 2002). Taking into account that the total wetland area is estimated to be 3,380 km² and large areas are expected to desiccate during dry seasons (Scott and Carbonell; 1986), an original peatland area of about 1,700 km² for French Guiana may be realistic. Because large tracks of coastal swamps have already been destroyed for agriculture and shrimp farming (Scott and Carbonell, 1986), the current peatland area can be assumed to be less.

Guyana

In the north of the Guiana subregion, the ancient landmass of the Guiana Shield occupies an area of approximately one million km^2 which includes some 50 more or less isolated table mountains called 'tepuis'(Eva and Huber, 2005). These flat topped table mountains of between 1,200 and 3,000 m height often harbour waterlogged soils that stores organic material (Junk *et al.*, 2011).
Peat soils occur in palm swamps, broadleaved swamp forest, open swamps and in the broadleaved meadows in the Guyana highlands (Guyana Forestry Commission, 2011; Huber, 2006). The most extensive stands of permanent flooded swamp forest on peat were found in the North West District of Guyana and in the Delta Amacuro (ter Steege and Zondervan, 2000). Swamp forest is also found in the 'White sands area' with its gently rolling aspect and its drainage pattern of blackwater streams.

Figure 28 shows the wetland vegetation types of Guyana. Open swamps, Coastal swamp forests and Broadleaved upland meadows usually deposit peat (cf. ter Steege, 1999; Huber, 2006) and combined cover an area of 12,700 km². How much peatland occurs in the mangroves and the Mixed forest/ Swamp forest complex (Figure 28) remains unclear. All swamp and marsh forests together cover an area of 26,899 km².

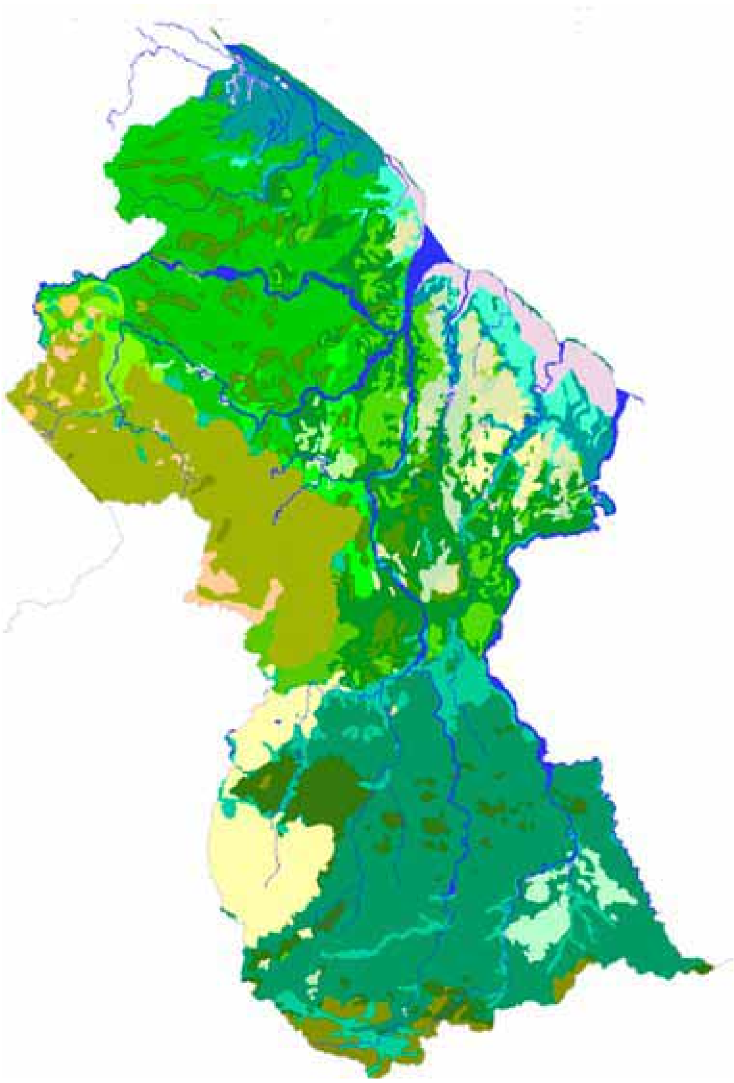


Figure 28. Vegetation map of Guyana showing selected vegetation types (after Alder and van Kuijk, 2009). The large turquoise area in the south indicates ‘Mixed Forest of South Guyana’ (not included in the legend) and not the ‘Mangrove forest’ that is indicated with a similar colour.

Peatland use and degradation

Much of the former seasonally flooded palm marsh and swamp forests along the rivers in eastern Guyana were cultivated by the Dutch (ter Steege and Zondervan, 2000). Repetitive burning has led to large-scale herbaceous and grassy swamps, interspersed with Mauritia palm trees. Overall forest degradation and deforestation in Guyana is estimated at some 640 km^2 per year. To what extent peat soils are affected is unknown.

Carbon stock and greenhouse gas emissions

Peat soils along the coast may store > 1900 tonnes C ha^{-1} with each 10 cm of peat contributing approximately 245 tonnes C ha^{-1} (ter Steege *et al.*, 1999). According to ter Steege (2001) the soil organic matter up to one meter depth is 490 tonnes ha^{-1} in pegasse (peat) soils. There also have been used more conservative figures (e.g. Alder and van Kuijk (2009) for swamps and marshy areas of 167 t ha^{-1}). Forest degradation and deforestation in Guyana is responsible for a loss of 12.8 million tonnes C per year, or a CO_2 release of 46.9 Mtonnes CO_2-e (Alder and van Kuijk, 2009). It is unknown if the peat soils are adequately included in this figure.

Opportunities for emissions reductions and enhancement of other ecosystem services

While combating climate change, the government of Guyana plans to drain large coastal areas including 55,000 ha of state-owned, “uncultivated” coastal lands. The Office of the President (2009) considers much of Guyana’s several hundred thousand hectares of non-forested land to be available for intensive agricultural development, which requires drainage and irrigation (e.g. in the Canje Basin). Care has to be taken not to drain organic soils and – if unavoidable – to focus on wet agriculture (paludicultures).

Suriname

Peatland distribution

The coastal wetlands of Suriname cover an area of about 18,000 km² (Junk, 1993). Alluvial plains with riverine marshes, freshwater swamps, large areas of swamp forest, rain-fed peat swamps and/or Mauritia flexuosa palm swamps include the Nanni swamps (2,700 km²), the Coronie Swamps (3,000 km²), the wetlands along the Coesewijn and the Saramacca River (2,000 km²) and the Wanekreek wetlands (700 km²) (Figure 30). In these wetlands a peatland area of 8,400 km² can be expected (cf. Table 13).

Table 13. Forest types of "insufficiently drained soils" of Surinam (after FAO, 2010).

National class	Area 1998 (ha)	Definition
High Swamp forest	485 300	- very wet conditions all year round - at least 20 meter high with two storeys and fairly closed - peat soils
Low Swamp Forest	239 200	- wet conditions all year around - open scrub to a low closed forest - one single storey of 10 to 15 meter height - peat soils
Mangrove Forest	114 600	closed forests with one storey- undergrowth restricted to ferns
Marsh forest (mostly on alluvial sediments)	463 65	- insufficient drainage causing seasonal fluctuations in moisture conditions from very dry to very wet - clay soils

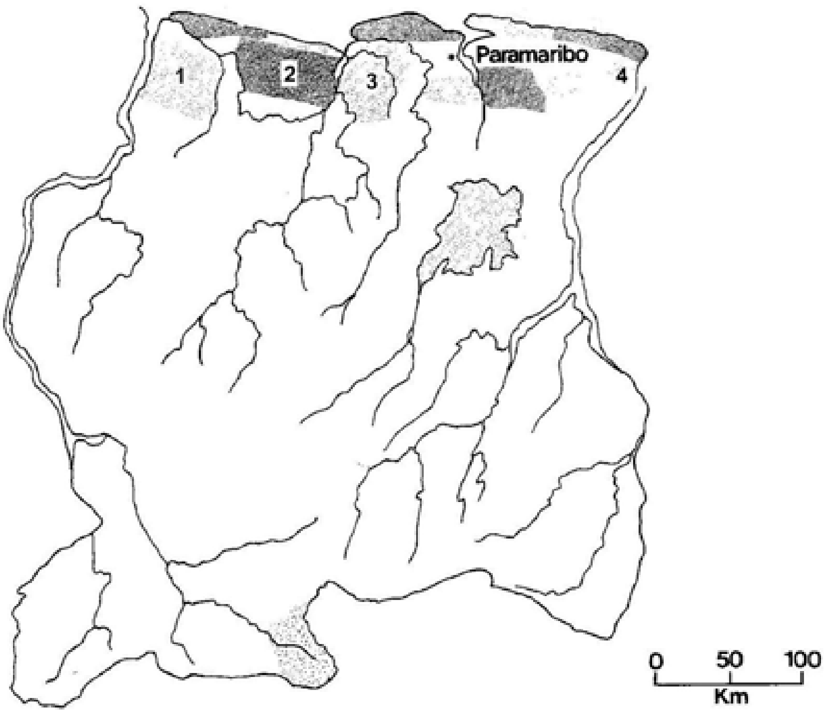


Figure 29) Wetlands of Suriname (after Scott and Carbonell, 1986), which might harbour extensive peatlands. 1: Nanni swamp; 2: Coronie Swamps; 3: wetlands of the the Coesewijn and the Saramacca River; 4: the Wanekreek wetlands.

Coastal peat soils of Northern Suriname are characterized by an organic 'pegasse' layer more of than 50 cm thick consisting of more or less decomposed forest litter (van der Eyk, 1957). In the central parts of these swamps, the peat often reaches a thickness of 125 to 250 cm (Figure 30). Large, rain-fed domed peatlands have been described by Brinkman and Pons (1968).

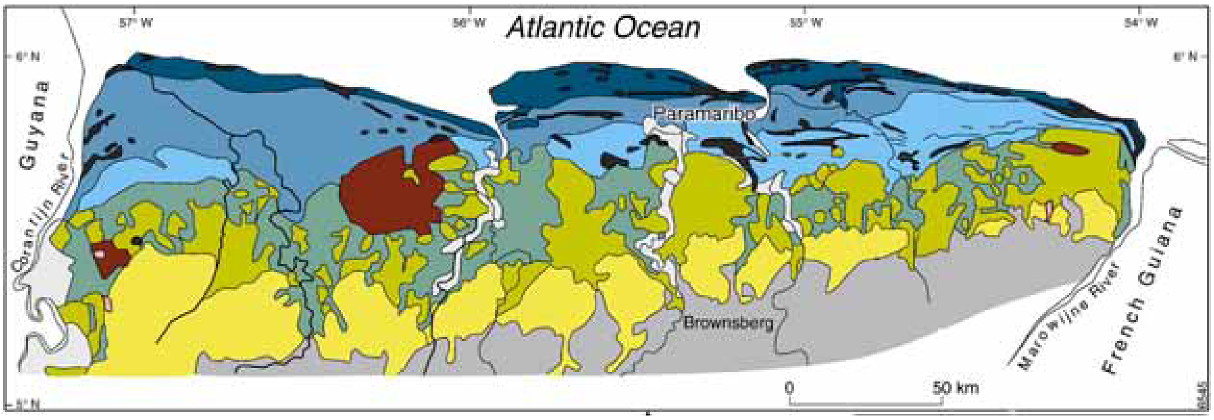


Figure 30. Geological map of the coastal plain of Suriname. Brown: ombrogenous (rain-fed) peat; grey: pyritic clays, peaty clays and peat ("Mara" formation; after Wong, 2009).

Peat or peaty soils also occur in the southern part of the middle belt of Suriname. There, the low-relief plains are dissected by stream valleys that form a rather regular drainage pattern. In the flat bottoms of such streams peats and peaty deposits occur (van der Eyk, 1957).

Shrier (1985) mentions a "mire area" for Suriname of 1,130 km^2 of coastal swamps, whereas according to Van Engelen and Huting (2002) 5 932 km^2 of Histosols exist. In consideration of the available information (e.g. Scott and Carbonell, 1986) the latter estimate seems more realistic, but more comprehensive and reliable data on the peatlands of Suriname are urgently needed.

Peatland use and degradation
Threats to Surinam's swamp forests are diverse. They include drainage of swamps for agriculture, damming for water storage and agriculture, grass and peat fires, discharge of agrochemicals, introduction of exotic plants, development of roads and transport canals, swamp forest exploitation (drainage and canalizing for logging), bauxite mining and other industrial development (Teunissen, 1993). At least 75% of the swamp forest area has been burned and is now covered with secondary swamp wood, swamp scrub or herbaceous swamp (FAO, Country Report Surinam, 2010; https://secure.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0149_full.html#location).

About 85% of the land suitable for agriculture lies in the coastal area including the fertile soil of the young coastal plain and the large freshwater swamps and rivers in the north. Since the arrival of the Europeans in the 17th century, about 2,000 km^2 of this land (mostly wetlands) has been turned into plantations and polders. Upon clearing for rice the peat layer is usually stockpiled and sometimes burned. When developed for dry cropping, the peat layer is generally incorporated in the topsoil (Tjien Fooh, 2007).

At several places, roads, dams and canals are crossing the swamps, even at places where there's no other human activity. These structures may dramatically change the local hydrology and vegetation over large areas, e.g. the Burnside-Wageningen road, the drainage diversion dam south of the Nickerie rice area, the MCP canal and the dam south of the Coronie rice polders (Tjien Fooh, 2007).

Carbon stock and greenhouse gas emissions
Usually a thin (<20 cm) to moderately thick (20–40 cm) peat layer is present in the swamp forest areas, but the peat layer may be considerably thicker (Noordam, 2007). Large amounts of CO_2 and other gasses are released to the atmosphere through burning of vegetation and peat. One cm of peat contains approximately 5 t C per ha (Noordam, 2007).

Opportunities for emissions reductions and enhancement of other ecosystem services

It is expected that in the coming years considerable areas of swamp vegetations, including coastal wetlands will be turned into agricultural, residential and/or aquaculture land if there are no proactive measures taken to prevent this. Because clearing the herbaceous swamps is cheaper, people have preferred to take them into use instead of (high) swamp forests. However, with increasing pressure on the land near Paramaribo, also these forests are threatened to be cleared (Tjien Fooh, 2007).

Surveying a burned peat swamp.
Photo: Marcel Silvius

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Peatland drainage - mainly for agriculture, grazing and forestry - and peat fires are responsible for almost one quarter of carbon emissions from the land use sector. By conservation, restoration and better management, organic soils and peatlands can make a substantial contribution to reducing atmospheric greenhouse gas concentrations.

This report informs on management and finance options to achieve emissions reductions and enhance other vital ecosystem services from peatlands. A decision support tree guides through opportunities for both cultivated and uncultivated peatlands. Methodologies and data available for quantifying GHG emissions from peatlands and organic soils are summarized and practical solutions are given concerning measuring, reporting and verification (MRV) and accounting. Country-specific case studies illustrate the problems, solutions and opportunities of peatland management. This report is a good handbook for policy makers, technical audiences and others interested in peatlands.

This report is a first version of the publication to which we would welcome any feedback or input.

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